1990-09

Tactical EO/IR system for ground forces

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(2)

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

TACTICAL EO/IR SYSTEM
FOR
GROUND FORCES

by

Hyung Suk Kim

September, 1990

Thesis Advisor: Edmund Alexander Milne

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution is unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION Naval Postgraduate School	6b. OFFICE SYMBOL (If applicable) 3A
7a. NAME OF MONITORING ORGANIZATION Naval Postgraduate School	
6c. ADDRESS (City, State, and ZIP Code) Monterey, CA 93943	7b. ADDRESS (City, State, and ZIP Code) Monterey, CA 93943
8a. NAME OF FUNDING/SPONSORING ORGANIZATION	8b. OFFICE SYMBOL (If applicable)
9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER	
8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
TACTICAL EO/IR SYSTEM FOR GROUND FORCES

12. PERSONAL AUTHOR(S)
Hyung Suk Kim

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Master's Thesis	FROM ______ TO ______	September, 1990	87

16. SUPPLEMENTARY NOTATION The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense of the U.S. Government.

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Electronic Warfare, EO/IR system, Ground EW system, Tactical EW sytem, Korea

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This thesis describes the tactical EO/IR system requirements and characteristics for the Republic of Korean Army. Many key ideas of these are centered on rough terrain condition, severe weather condition and tactical usage of EO/IR system in Korean peninsular. And finally, the future trends of ground tactical EO/IR system and some recommendations for Korean Army are presented.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL E.A. MILNE	22b. TELEPHONE (Include Area Code) (408) 646-2886 · 22c. OFFICE SYMBOL PH/Mn

DD Form 1473, JUN 86 Previous editions are obsolete SECURITY CLASSIFICATION OF THIS PAGE
S/N 0102-LF-014-6603 Unclassified

Approved for public release; distribution is unlimited.

Tactical EO/IR System for Ground Forces

by

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Captain, Republic of Korea Army
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Submitted in partial fulfillment
of the requirements for the degree of

MASTER OF SCIENCE IN SYSTEMS ENGINEERING
(ELECTRONIC WARFARE)

from the

NAVAL POSTGRADUATE SCHOOL
September 1990

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ABSTRACT

This thesis describes the tactical EO/IR system requirements and characteristics for the Republic of Korean Army. Many key ideas of these are centered on rough terrain condition, severe weather condition and tactical usage of EO/IR system in Korean peninsular. And finally, the future trends of ground tactical EO/IR system and some recommendations for Korean Army are presented.

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ACKNOWLEDGEMENTS

I would like to express my appreciation to Professor Edmund Alexander Milne, whose conceptual and practical knowledge of the EO/IR system is most impressive, was very helpful in providing many substantive suggestion on how to improve this thesis. Professor Wayne Philo Hughes, who made many useful suggestions on each of the chapters.

I would like to thank my son, Jin Huy, who was born and grew up in Monterey.

Finally, I wish to express my appreciation to my wife, Young Seol, for her patience during the course of my studies and for all of the assistance that made this work possible and to whom it is dedicated.

I. INTRODUCTION

Electromagnetic energy possesses a very real potential for functional impairment and/or destruction of certain targets. Whenever electrons are accelerated electromagnetic waves are produced. These waves are described by quantum mechanics as having both *wave like* and *particle like* characteristics. The *particle like* packets are called photons and possess discrete amounts of energy described by the formula $E = h\nu$ where h is Plank's constant and ν is frequency.[Ref. 1:p.41] Electrooptics (EO) is defined as the interaction between optics and electronics leading to the transformation of optical energy into electrical, or vice versa, with the use of an optical device.[Ref. 2:p.3n-1] A Laser is a typical example of an electrooptics phenomenon.

Infrared (IR) refers to the portion of the electromagnetic spectrum lying between the visible and the short wavelength microwaves. Sir William Herschel discovered the presence of energy in this region of the spectrum in 1800 while exploring the distribution of energy in the solar spectrum.[Ref. 3:p.21-1] The IR spectrum can be roughly divided into three parts; the near IR from 0.8 to 1.2 μm, the intermediate IR from 1.2 to 7.0 μm, and the far IR from beyond 7.8 μm. The region from 1.2 to 12.0 μm is the most important from the military standpoint as this is the region in which the photo-conductive detectors are useful. This is also the region which most of the IR radiation from military target falls.[Ref. 3:p.21-1,2] Some of our military experts may not be fully aware of the importance of EO/IR weapons in modern warfare. While most of them are aware of the dramatic history and effectiveness of the Sidewinder air-to-air missile in combat because of the extensive television and printed news coverage, they believe that Radio Frequency (RF) guided missiles have accounted for most kills on hostile aircraft in recent years. But based on the Appendix A, this is not so true. In the time period between 1979 and 1985, 90% of all known aircraft losses were attributed to IR missiles.[Ref. 4:p.41] And we have to consider the massive use of night-sights for foot-soldiers, the extensive use of IR night-vision devices on tanks, the employment of Forward Looking Infrared Reconnaissance System (FLIR) and the guidance system on the IR Marveric missile.[Ref. 4:p.42] The reason for this is clearly the EO/IR technology produces the ideal weapons in the complex modern warfare.

Military application of EO/IR systems are even more varied than systems operating in the RF portion of the electromagnetic spectrum. The military systems may be defined as active (emit radiation) or passive (does not emit radiation). A passive system has the advantage that it does not emit the radiations that may warn an enemy of the threat imposed. For some applications, the emission of radiation is essential. One important advantage of these systems is that, because of the extremely short wavelength, very high resolution systems can be built with very small apertures.[Ref. 2:p.3p-1] For example, a 0.05 milliradian resolution can be attained, corresponding to a 10 cm aperture at the range of about 1.8 km at 4.1 μm wave length.

In the ground environment, Electronic warfare (EW) can be considered as another tactical weapon for a local commander's selection and employment. One might conceive of strategic uses of EW, such as widespread deception through transmission of false messages, but since these uses are limited in scope, only tactical applications of EW will be considered here. Tactical weapons should be employable down through the basic combat units. The EO/IR tactical weapon, because of its electromagnetic properties, can have effects on areas other than those occupied by the combat unit and its immediate opponents. The objective of this thesis is based on these ideas. We will give the guidelines to a project manager or to a beginner in EW research about EO/IR system acquisition and development. EW has long been concerned with particular techniques to defeat certain equipment. But EW does not exist in imaging, or EO/IR situations. Thus we need a broader understanding of EW concepts so that we can properly evaluate their requirements. The first stage of any weapon system's life cycle is the concept definition stage. For the EO/IR system, in Korea, there is no distinct concept related to definition of EW and EO/IR systems. We also have some confusion about EO/IR as a subsystem of EW system. This is not so good condition for the future conflict in korean peninsula that EW is very important force multiplier of the modern battle field. So, in chapter 2, the author will review the concept and the definition of EW system and EO/IR theory. This will help us with the prospective relationship between the current EW system and the EO/IR subsystem. In chapters 3, 4 and 5 we will see the system requirements, characteristics and the critical issues in the system test and evaluation for ground forces. Many key ideas in these chapters will be centered on rough terrain and severe weather condition. In chapter 6 and 7, we will see the future trends and recommendations of this ground EO/IR system.

II. THEORETICAL BACKGROUND FOR EO/IR SYSTEM

A. DEFINITION

The basic concept of electronic warfare is to exploit the enemy's electromagnetic emission in all parts of the electromagnetic spectrum in order to provide intelligence on the enemy's order of battle, intentions and capabilities and to use countermeasures to deny effective use of communications and weapons systems while protecting one's own effective use of the same spectrum.[Ref. 5:p.1] Some definitions of the electronic warfare related terms are described in the following manner. [Ref. 2:p.1A-1] EW is military action using electromagnetic energy to determine, exploit, reduce or prevent hostile use of the electromagnetic spectrum, and action that retains friendly use of the electromagnetic spectrum. There are three distinct parts in EW; ESM, ECM and ECCM.

Electronic Support Measures (ESM) are actions taken to search for, intercept, locate, record and analyze radiated electromagnetic energy in order to exploit such radiations in support of military operations. Thus ESM provides a source of EW information required to conduct Electronic Countermeasures (ECM), Electronic Counter - Counter Measures (ECCM), threat detection, warning avoidance, target acquisition, and homing. The other parts of electronic support measures are Signal intelligence (SIGINT) and Telemetry intelligence (TELINT). Generally speaking ESM means tactical ESM and the SIGINT and TELINT are based on the strategic concept. SIGINT is a generic term that includes both Communications Intelligence (COMINT) and Electronic Intelligence

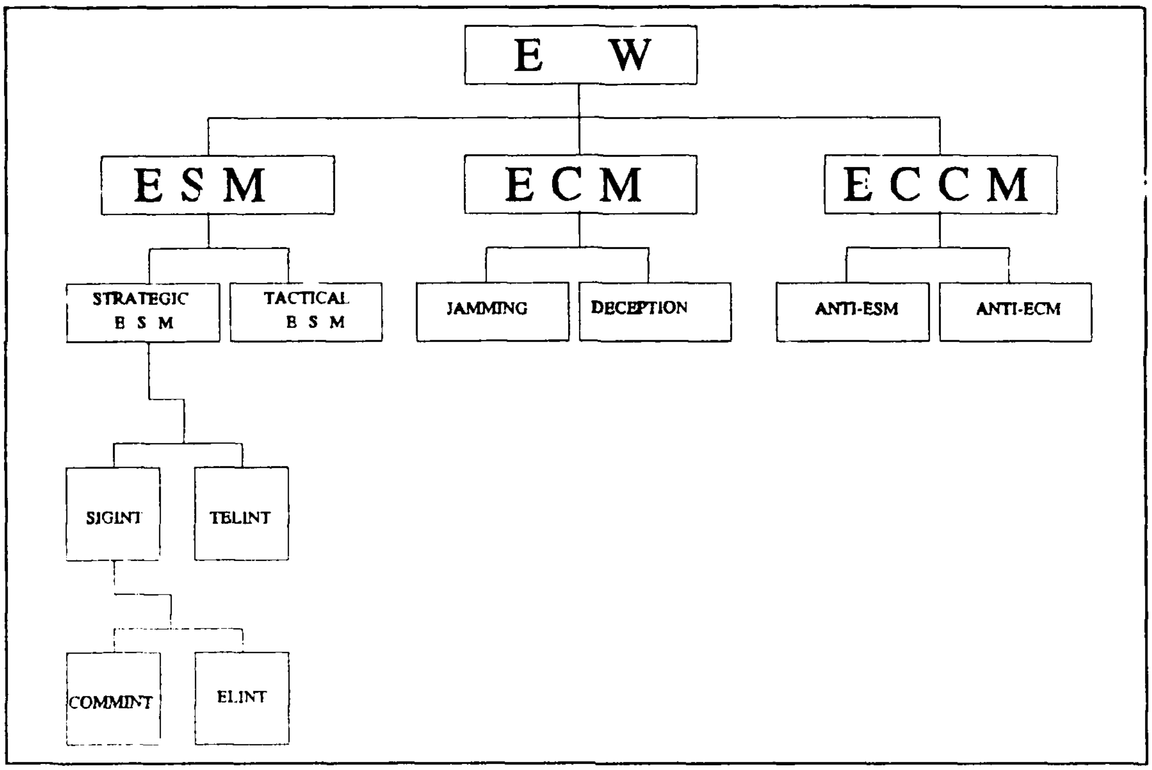


Figure 1 EW organization

(ELINT). COMINT is technical and intelligence information derived from foreign communications by other than the intended recipients. ELINT is the product resulting from the collection, evaluation, analysis, integration and interpretation of all available information concerning foreign nations or area of operation that are significant to Electronic Warfare. TELINT is the collection and processing of foreign telemetry radiation. So the key functions of ESM are intercepting, identifying, analyzing and locating sources of hostile radiations.

The second category, ECM, involves action taken to prevent or reduce an enemy's effective use of the electromagnetic spectrum. Typically their functions are jamming and deception. Jamming is the deliberate radiation or reflection of electromagnetic energy with the object of impairing the deployment of electronic devices, equipment, or systems being used by a hostile force. Deception is the deliberate radiation, reradiation, alteration, absorption or reflection of electromagnetic energy in a manner intended to mislead a hostile force in the interpretation or use of information received by his electronic systems. The two categories of deception are manipulative and imitative. Manipulative implies the alteration or simulation of friendly electromagnetic signals to accomplish deception, while imitative consists of introducing radiation into hostile channels which imitates a hostile emission.[Ref. 5:pp.9-10] So the objective of ECM systems are to deny the enemy's information seeking, or to surround his return with so much false target data that the true information can not be extracted, or to supply false data that the information handling capacity of the victim system failed.

ECCM are actions taken to ensure friendly use of the electromagnetic spectrum despite the use of ECM. These actions involve the use of ECCM equipment, equipment features, operational techniques and tactics. ECCM is mostly concerned with techniques which are embodied in the design of electronics equipment, while ECM usually requires separate items of equipment which operate in their own right and not as an adjunct to other systems.[Ref. 5:p.17]

ECM and ECCM acts like the series of chains. Figure 2 shows a typical ECM - ECCM chain. A truism in the ECM/ECCM world is that any EW or communication system can be jammed and any ECM can be countered, depending on the resources which either side is willing to commit. We wish to emphasize that EW depends on the radiation of electromagnetic energy and not on electronics only. Hence EW includes systems using

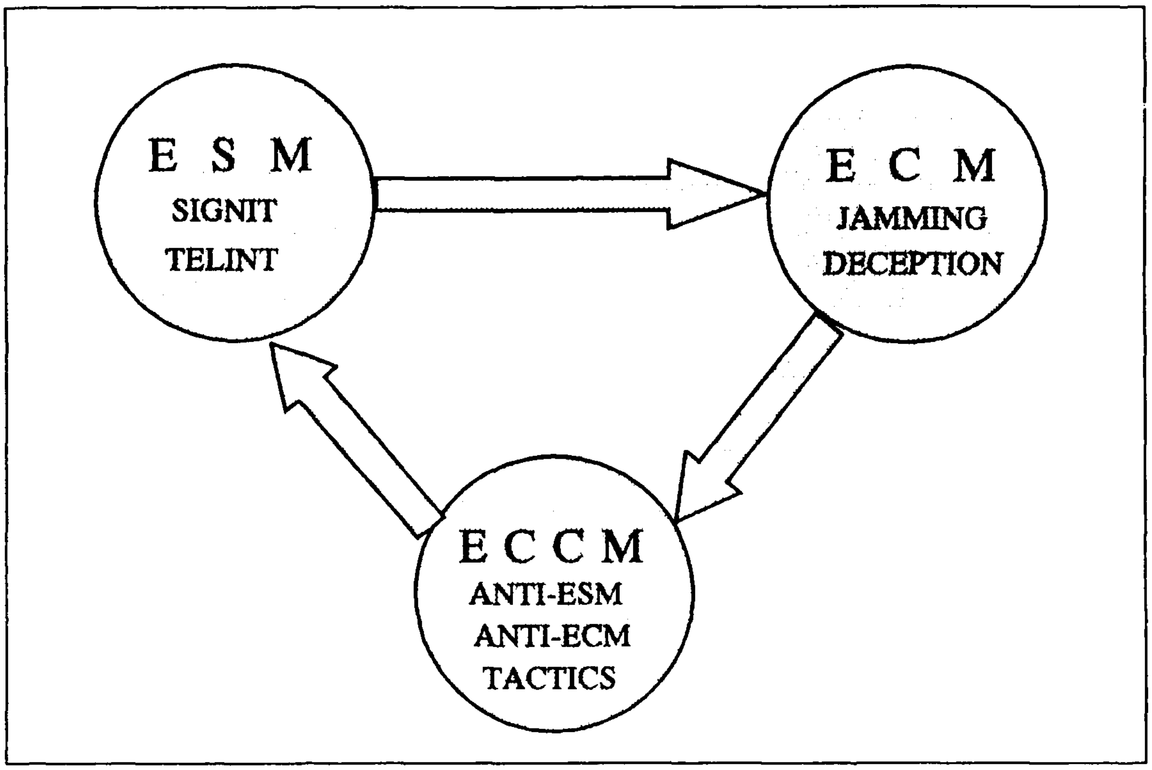


Figure 2 The typical ECM ECCM chain of action

all forms of electromagnetic energy, for example, radio, radar, infrared, optical system, laser and radiation produced by nuclear weapons.

EO/IR systems generate and detect light by using sophisticated oscillators and very high sensitivity detectors. Scientists and engineers designing EO/IR weapons systems are most interested in the 0.3 μm to 12 μm wavelength band. These wavelengths are the most practical for military applications due to atmospheric conditions and the types of probable targets. Some other specialized military applications, however, use ultraviolet and very far-infrared wavelengths. Normally, laser and thermal imaging technologies are included in EO/IR systems. Each is often a major subsystem of a high-level system. Figure 3 shows the brief description of those spectral regions.

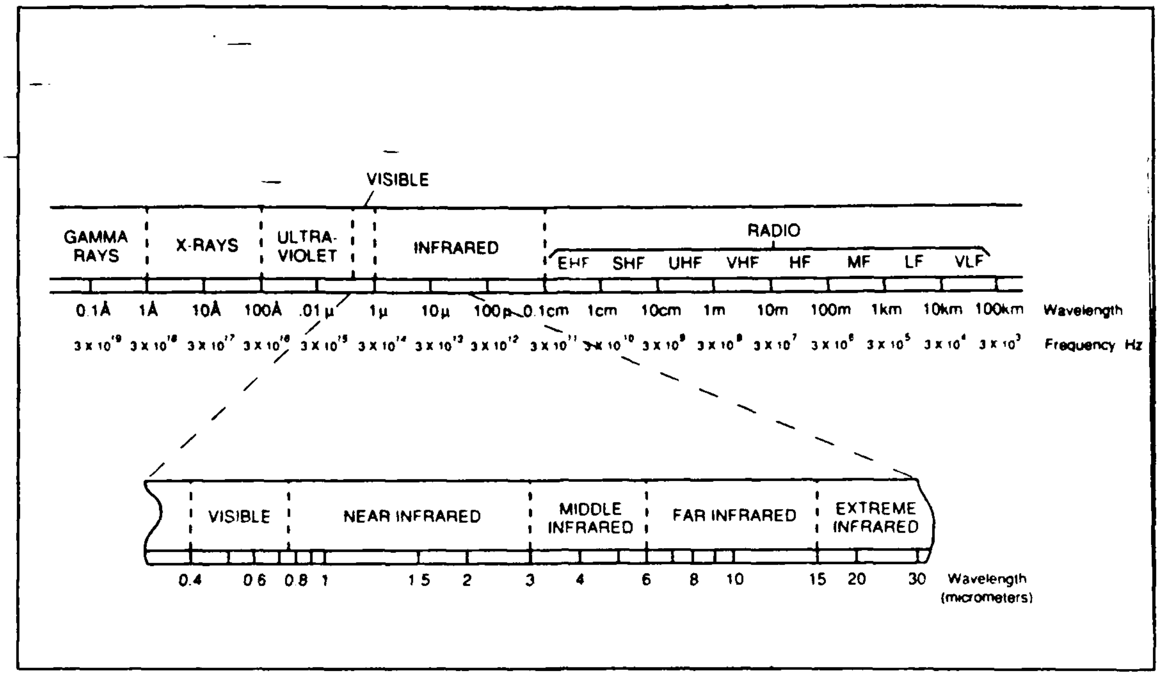


Figure 3 Typical EO/IR spectral region

Typical types of EO/IR functions are early warning, ground controlled intercepter, target acquisition, height finding, target tracking, fire control, air intercepter and missile guidance. EW is electromagnetic and it uses as its battle ground the total spectrum of electromagnetic radiation. EO/IR does almost the same as the EW function. The only difference is the applicable portion of electromagnetic spectrum. So EO/IR is a tool of EW. Most people think that the EW depends only upon the RF portion of the spectrum. But if we could say EW is a conflict of electromagnetic spectrum, then half of EW operation is conducted with the EO/IR portion of spectrum. In today's threat environment, a properly coordinated combination of reliable EW assets and *hard kill* weapons has become an essential element of an enemy defense system. ESM will supply invaluable information regarding the type, composition and bearing of attack. Active

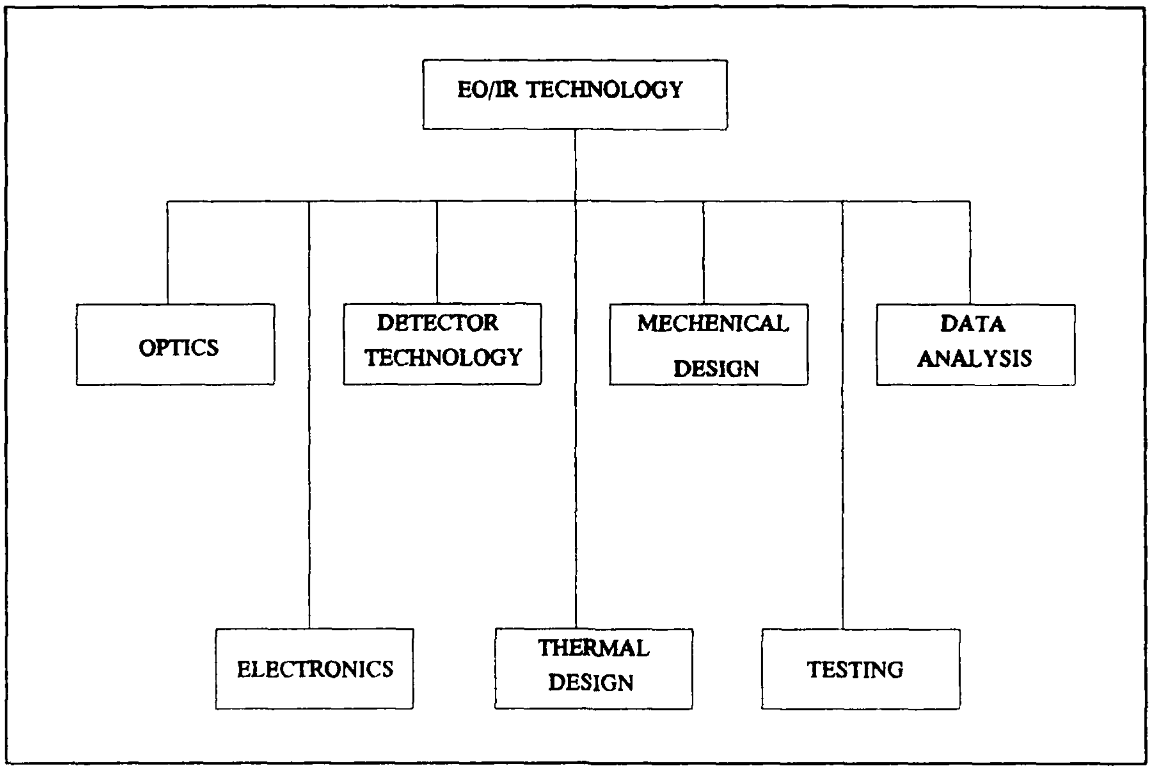


Figure 4 Major EO/IR field of technology

ECM will slow and confuse the timing and coordination required for mass attack; also it will support our defense system's hard weapon defenses by direct action against incoming missile seekers (through jamming, chaff, IR flares), thereby reducing the weight of attack.

B. EO/IR MILITARY APPLICATION

Although EO/IR has been part of the scientific world for over 150 years, its application for military purpose has only taken place within the last 40 years. Detection of objects in the dark, secure communication, and detection and homing on military targets by their natural IR radiation are a few of the many military applications of EO/IR system. But today, various basic types of EO/IR systems are used in conjunction with

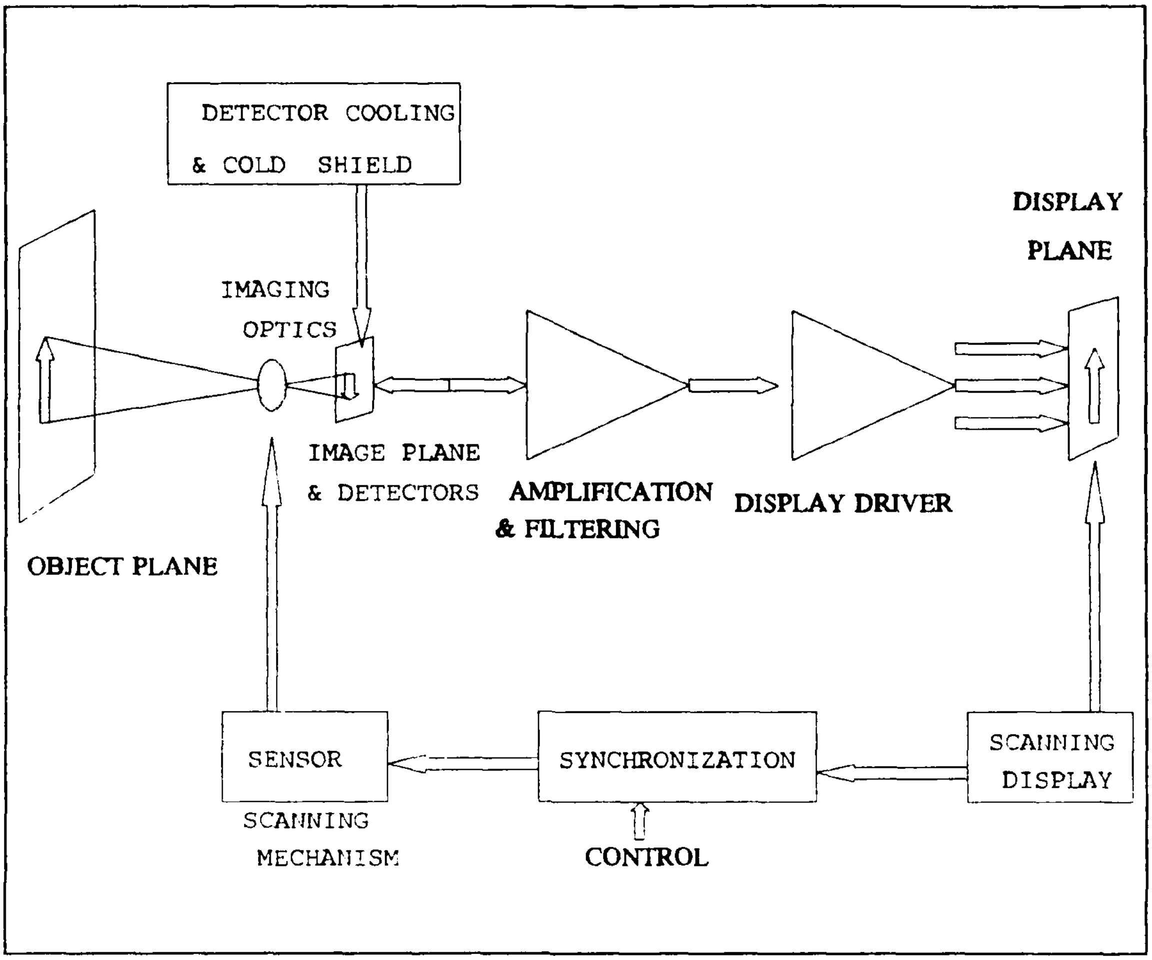


Figure 5 Typical IR imaging system

tactical weapons in military throughout the world. Following is the brief summary of notable applications of EO/IR military system.

1. IR Imaging System

The device converts the IR radiation into visible light for the night vision devices or battlefield surveillance. Forward-looking IR Reconnaissance System (FLIR) is the typical IR imaging system. It is designed for mounting on airborne platforms or ground vehicles to provide weapon system operators with IR target detection, acquisition, recognition and angle information. The FLIR systems, developed specially for nighttime

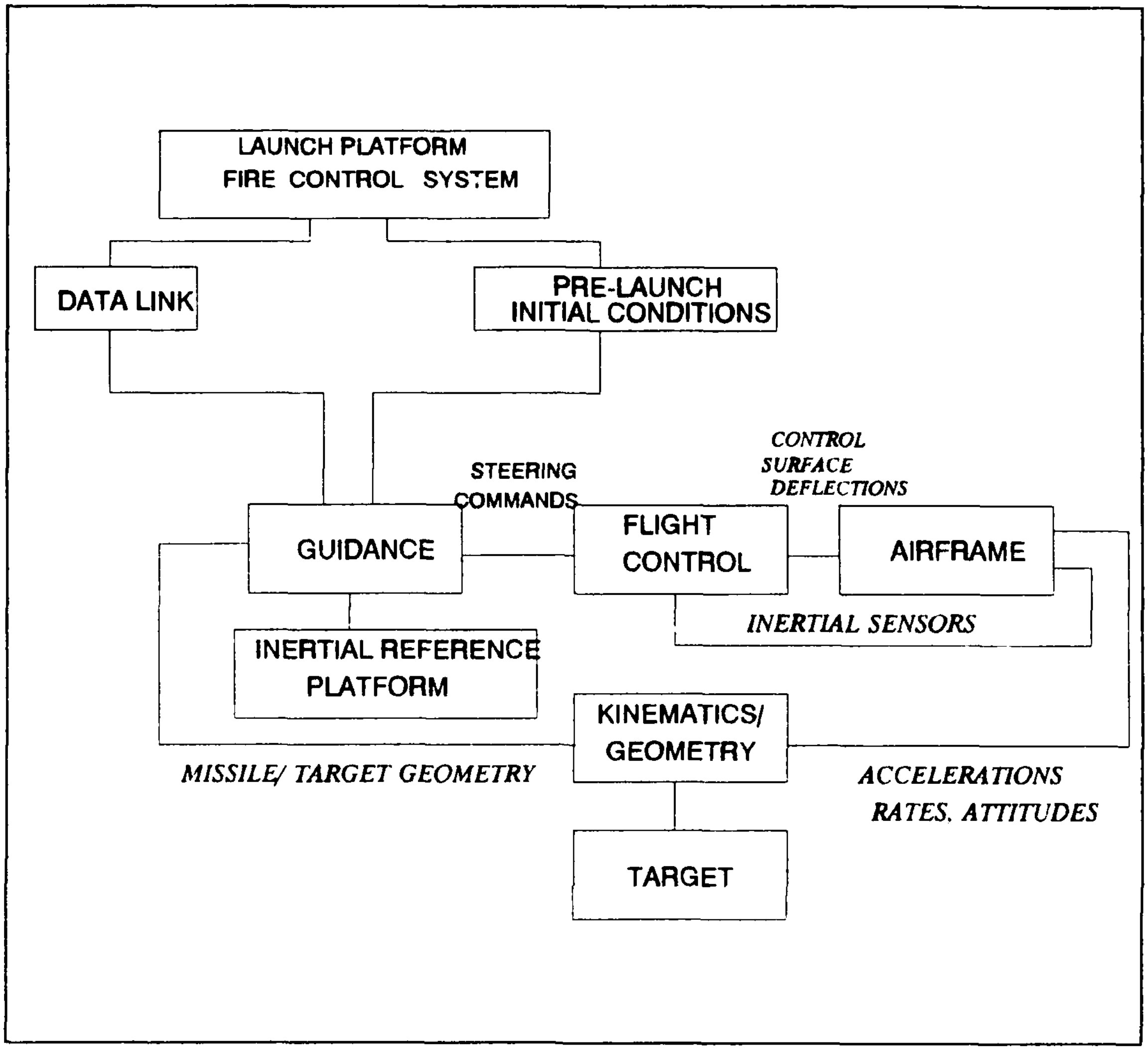


Figure 6 Tactical-missile function block diagram

use, provide real-time display of the terrestrial scene within the field of view (FOV) of the sensors.

2. Missile Guidance

This is the EO/IR application of missile guidance which, beginning about 1958 and extending to the early 1960's, the REDEYE missile was developed for the Army, to provide the foot-soldier with a defense against low-flying aircraft. The 9 kg missile, which is less than 8 cm in diameter and 1.2 m long, is aimed and fired from a shoulder-mounted launch tube.[Ref. 6:p.1-3] Many such modern missiles use the EO/IR guidance system rather than RF guidance system. The present state of EO/IR guidance system technology can be divided into three broad classes of device: (1) nonimaging IR systems that usually operate in either the visible or middle-IR (2 μm to 5 μm) band; (2) imaging seekers that operate in either the visible or far-IR (8 μm to 14 μm) band; and (3) laser seekers that use a laser as an illuminator - the most commonly used being in the 1.06 μm Neodymium-Yttrium-Aluminum Garnet (Nd:YAG) laser.[Ref. 7:p.38]

3. Search And Track Systems

This is for the search, acquisition and tracking of EO/IR sources. Generally, IRST is a non-imaging device, that looks at all the data available and makes a determination about the presence or absence of a target. The search and track device may be required to keep a full hemisphere (2π steradian) under constant observation, to have a resolution of one milliradian or less, and to operate without human assistance for long periods of time. This device is especially suitable for detection of targets with low radar cross section (RCS).

4. Ranging Systems

From the military stand point, one of the shortcomings of passive EO/IR equipment is that it does not readily provide information on the distance to a target, as radar does. EO/IR rangefinders derive range from measurements of angular rate, flux changes, or time-to-go determinations. IR rangefinders and laser rangefinders are the typical types of this application. Truly active pulse-operated IR laser rangefinders can

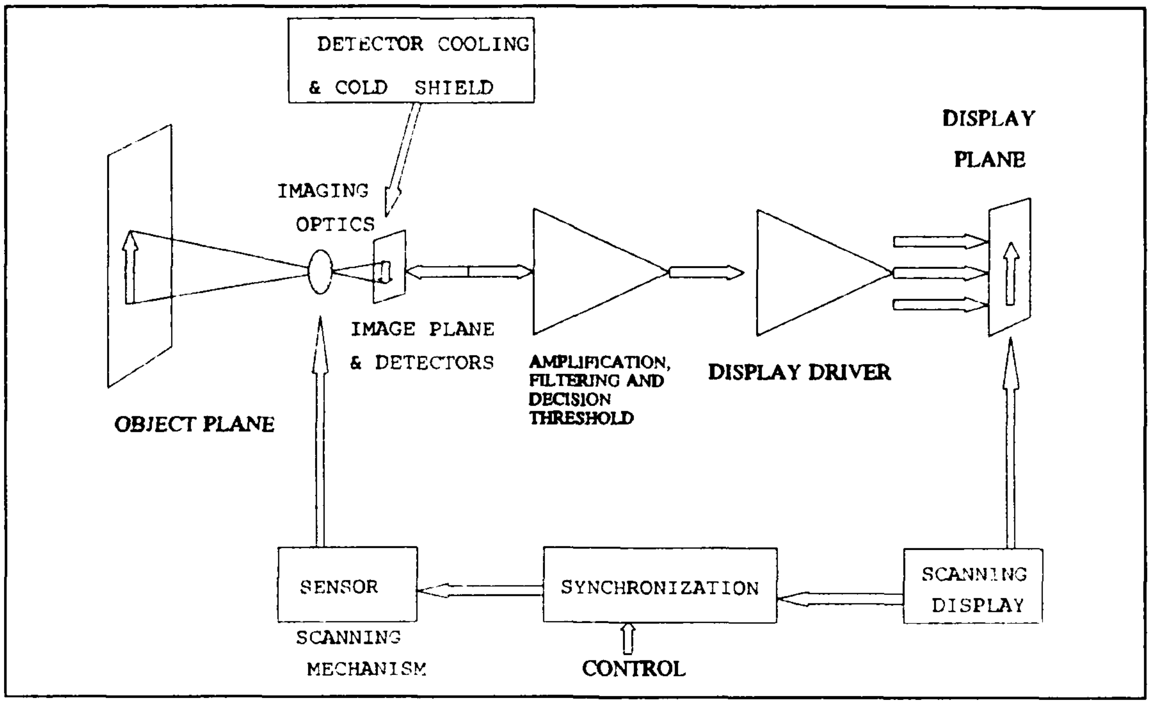


Figure 7 Typical IR search system block diagram

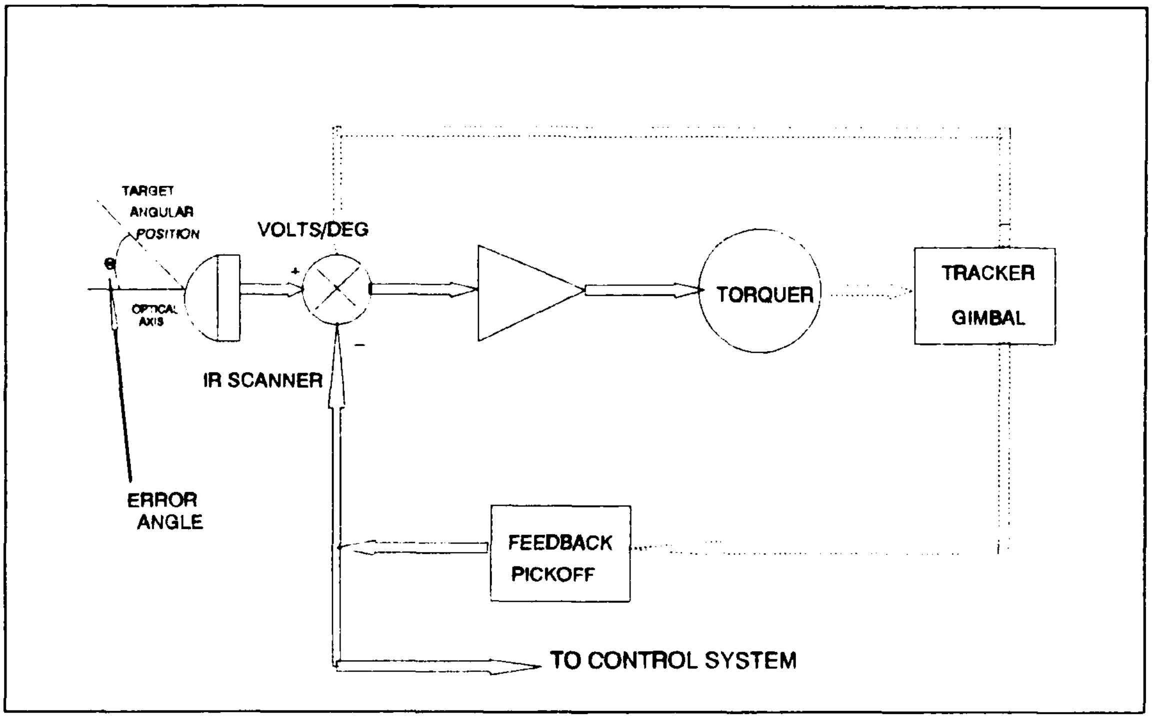


Figure 8 Typical IR tracker block diagram

be built, though their cost, complexity, and range limitations restricted their utility as radar replacements. However, lasers are recognized and important tools for precise measurement of distance. These laser rangefinders are now widely used in precision rangefinding and weapon guidance.

5. Advantages And Disadvantages

a. Advantages

The EO/IR system can be a passive or active system. Typically the EO/IR systems have small size and light weight compared to functionally similar RF systems. These systems have pretty low cost compared to a RF operation system.

Most military targets are camouflaged. However, The EO/IR systems act effectively against camouflage in the visible region of the optical spectrum. The EO/IR systems have many other advantages such as no minimum range limitation, greater angular resolution than RF radar, and minimum requirements for auxiliary equipment.

b. Disadvantages

Along with many advantages, EO/IR systems have several disadvantages. In poor atmospheric conditions, the capabilities will be reduced significantly. For example, IR systems are blinded by clouds, precipitations and IR radiations are subject to atmospheric absorption.

They also require some special equipment for the detector cooling (especially medium and far IR systems require proper cooling system). And finally, EO/IR devices have only line of sight (LOS) detection capability.

C. RELATED PHYSICS THEORY FOR EO/IR SYSTEM

1. Radiation Theory

All objects at a temperature above absolute zero emit IR radiation to some extent. A temperature above absolute zero causes the atoms of the body to vibrate. These vibrations result in the emission of IR radiations which can be detected at a distance with suitable equipment. The intensity of the radiation increases and the position of the peak intensity moves toward shorter wavelengths as the temperature is increased. To understand IR radiation emitted from a real world source, it is necessary to understand the theory of radiation from an ideal source. A blackbody represents a limiting case never quit reached by an actual body. Blackbody is a perfect radiator and absorbs all thermal radiation. It radiates at all wavelengths, and at any temperature its spectral radiant emittance reaches a maximum for a specific wavelength. The spectral distribution of energy in blackbody radiation is expressed by the following formula, known as Plank's radiation law:

$$W_\lambda d\lambda = \frac{2\pi c^2 h}{\lambda^5 (e^{ch/\lambda kT} - 1)} d\lambda \tag{1}$$

Where: $W_\lambda d\lambda$ is the radiant emittance within the wavelength band $d\lambda$.

c is the velocity of light (2.9979×10^8 m/sec)

h is the plank's constant (6.6256×10^{-34} Watt sec^2)

λ is the wavelength

T is the absolute temperature

k is Boltzmann constant (1.3805×10^{-23} Watt sec/K)

If the above expression is divided by $d\lambda$, the spectral radiant emittance W_λ is obtained. This is the radiant emittance per unit wavelength interval. If Equation (1) is differentiated with respect to λ and placed equal to zero, the value of the wavelength corresponding to the maximum value of the spectral radiant emittance is obtained. The resulting expression is

$$\lambda_{max}(\mu m) = 2897.8(\,\mu m\ K\,)/T(\,K\,)$$

This is known as Wien's displacement law. It shows that the maximum energy of the blackbody spectrum shifts toward shorter wavelengths as the temperature is increased. If $W_\lambda d\lambda$ is integrated over all values of λ then the total radiant emittance is obtained. This is known as the Stefan-Boltzmann law.[Ref. 3:p.21-2]

$$\int_0^\infty W_\lambda d\lambda = 2\pi c^2 h \int_0^\infty \frac{d\lambda}{\lambda^5 (e^{ch/\lambda kT} - 1)} d\lambda = \sigma(T^4) \qquad (2)$$

Where σ is Stefan's constant (5.668×10^{-8} Watt/m^2K^4)

This formula states that the total emissive power of a blackbody is proportional to the fourth power of its absolute temperature. Thus, the hotter an object is, the more energy it emits in the IR region.

The previous discussions and equations apply to a blackbody radiator. By modifying the equations with a factor that varies according to the source, these equations can be made applicable to greybodies. Greybodies are objects which have a radiation efficiency of less than 100%. The correction factor is called emissivity. Emissivity is the ratio of the radiant emittance of a greybody to the radiant emittance of a blackbody at the same temperature. Objects with a constant emissivity such as heated metal parts, personnel and environmental backgrounds can be approximated as greybody emitters. Objects which have an emissivity that is a function of wavelength are called selective radiators. They form a militarily important body of emitters such as combustion engine exhausts, rocket plumes and jet exhausts.

2. Absorption And Scattering

In use of IR radiation, the attenuating characteristics of the media must be considered. The performance of military systems for imaging, target detection, tracking, target designation, warning of missile launch or laser irradiation, optical fuzing or laser weaponry, is very strongly dependent on the transmission and modification of such radiation on an atmospheric path, and on the fluctuations in these effects also. The important atmospheric effects to be dealt with are refraction, absorption and scattering by the molecular constituents of the atmosphere and by the suspended particles in it, and the modulation transfer degradation, beam wander, beam broadening and scintillation effects caused by atmospheric turbulence. For work at low altitudes, carbon dioxide and water vapor in the atmosphere are the most important absorbing constituents. Radiation traveling through the atmosphere undergoes attenuation.[Ref. 8:p.1-1] Figure 9 shows the

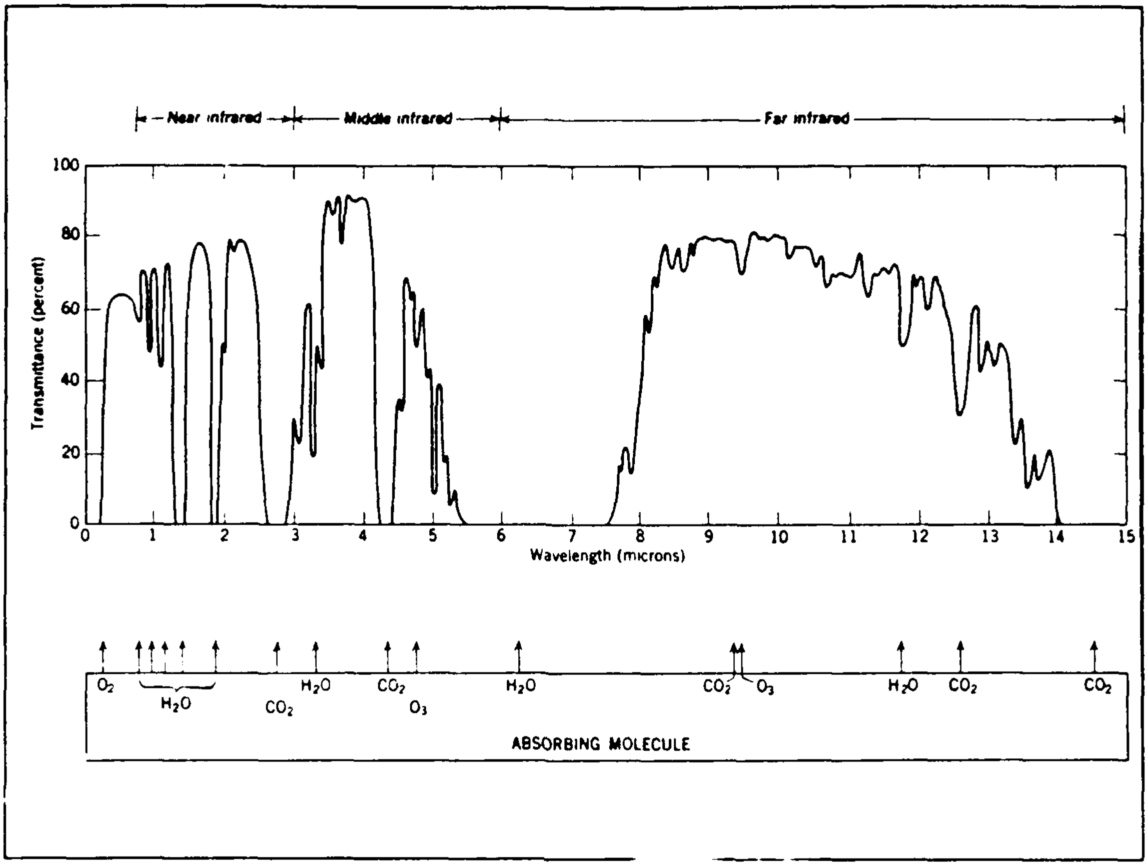


Figure 9 Transmittance of the atmosphere for a 1830 meter horizontal path at sea level containing 17 mm of precipitable water.

atmospheric transmission in a typical atmospheric condition.

3. Background Radiation

Background radiation can be due to self-emission and reflected or scattered radiation from terrain, sea surface, the atmosphere and atmospheric objects (aerosols) or celestial objects, or it can be due to various combinations of these. However, in this section, we will look at terrain radiation only. What is considered as a background or as terrain to one person may be considered as a target or a field of operations to another. Terrain radiation in the daytime and at wavelengths shorter than 4 μm is dominated by

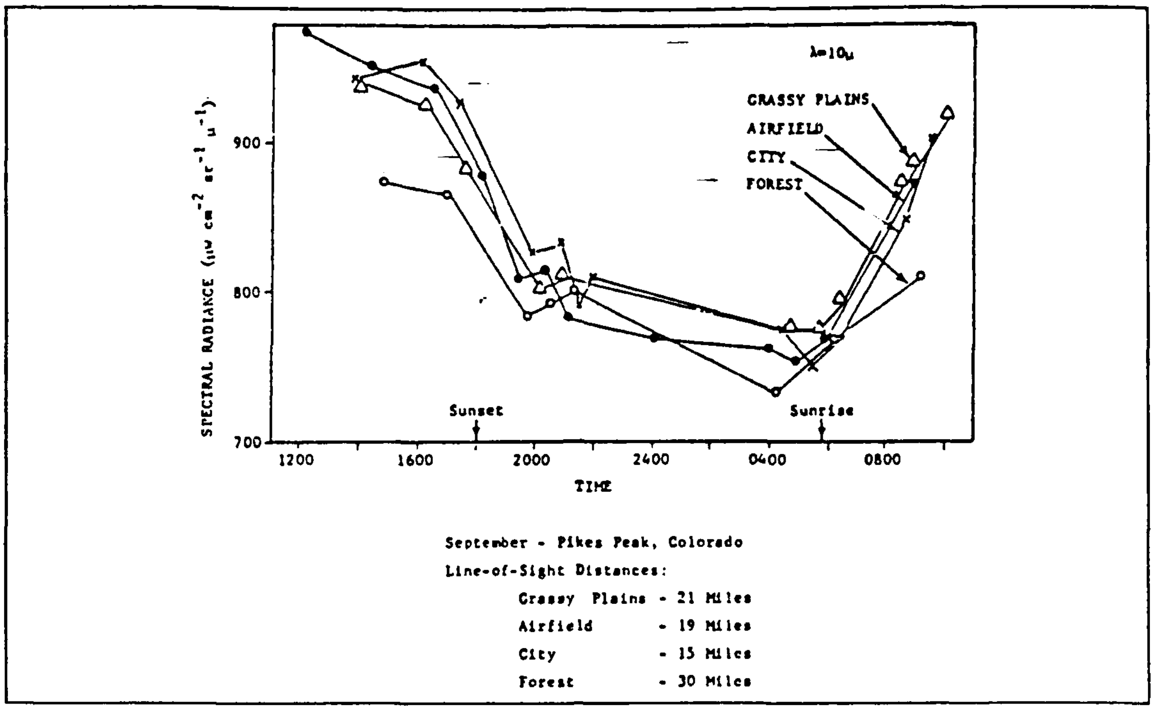


Figure 10 Typical diurnal radiance from various terrain features

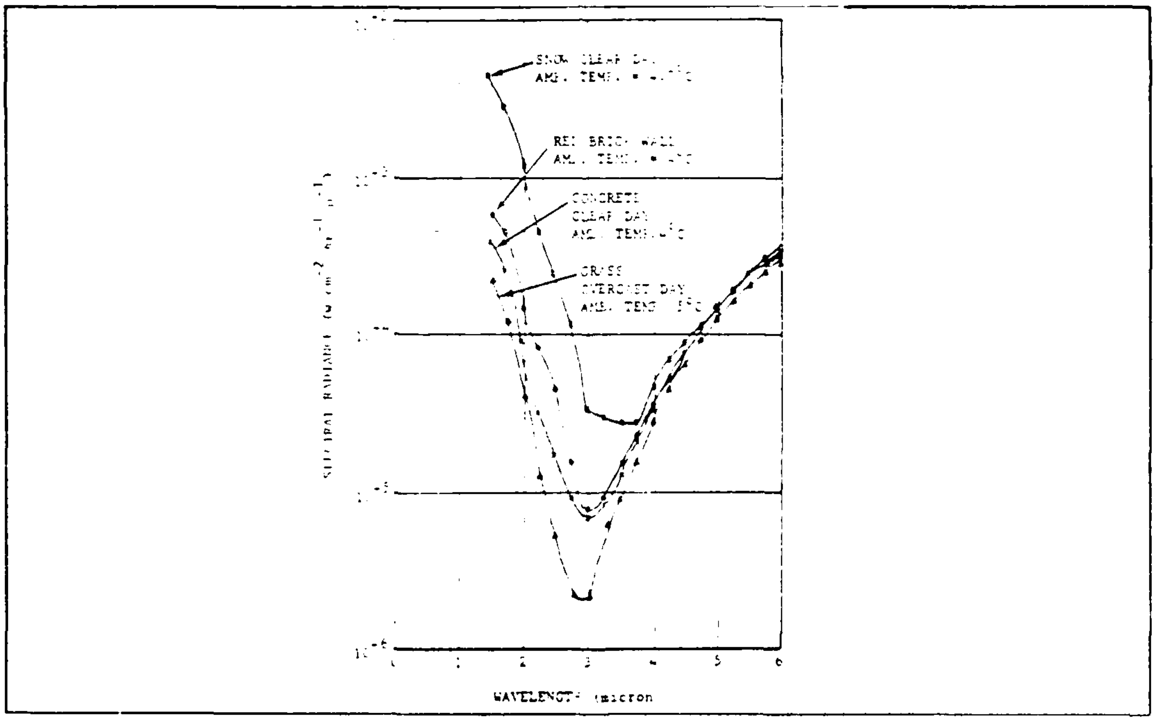


Figure 11 Spectral radiance from various terrain

sun light and by the reflectivity of background objects constituting the terrain. The reflectivity of background objects at wavelengths shorter than 3 μm ranges from 0.03 (bare ground) to 0.95 (fresh snow).[Ref. 6:p.2-71] Beyond 4 μm, the radiation from the terrain is dominated by the emission of terrain itself which depends on the temperature of the terrain objects and on their emissivities. In the daytime the temperature of the background objects is related to their optical properties in the visible and IR regions (6 - 15 μm), their thermal contact with the air and their heat conductivity and capacity. The cooling rate of background objects at night time will depend on their heat capacity, heat conductivity, thermal contact with the surrounding air, IR emissivity in the 8 to 12 μm band, atmospheric humidity, and cloud cover. In a vegetation area which is in close contact with the surrounding air, and water surfaces (lakes, rivers, beach) which have large heat capacities will radiate fairly evenly during the day and night. Figure 10 shows typical diurnal variation in radiance from various terrain backgrounds. Daytime spectral radiances from 1 μm to 6 μm of various terrain features are shown in Figure 11, which also shows a large spread in radiance values at wavelengths shorter than 3 μm where scattering of solar radiation predominates. Beyond 4 μm the radiance values of the various terrain features differ little. Concrete and brick walls have higher temperatures than grass and radiate more at wavelengths longer than 4 μm. At wavelength shorter than 3 μm, snow is an excellent scatterer or solar radiation and gives the highest radiance values while grass has the smallest reflectivity to sunlight at wavelengths shorter than 3μm and yields the smallest radiance values.[Ref. 6:p.2-71] Relative radiance measurements are often of more importance to system designers than the measurement

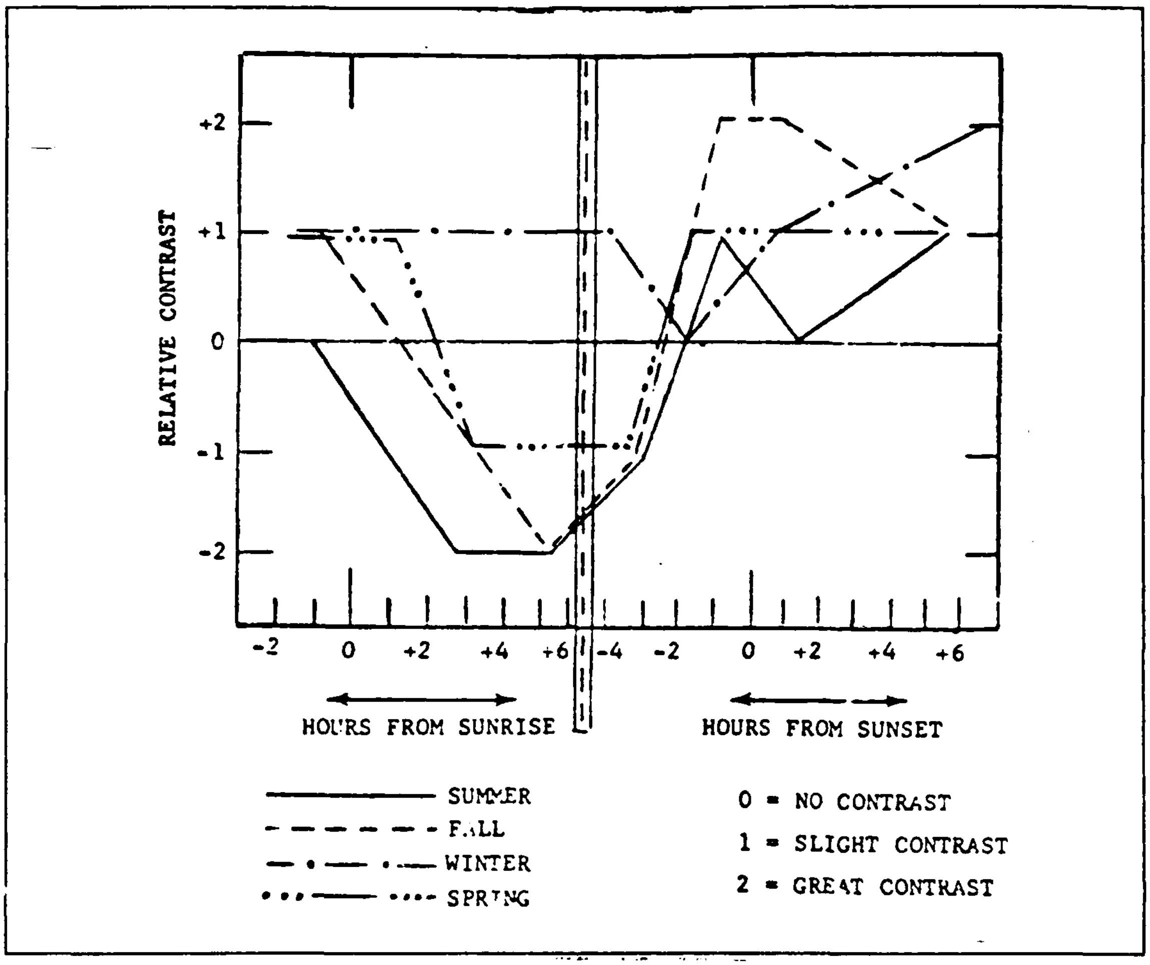
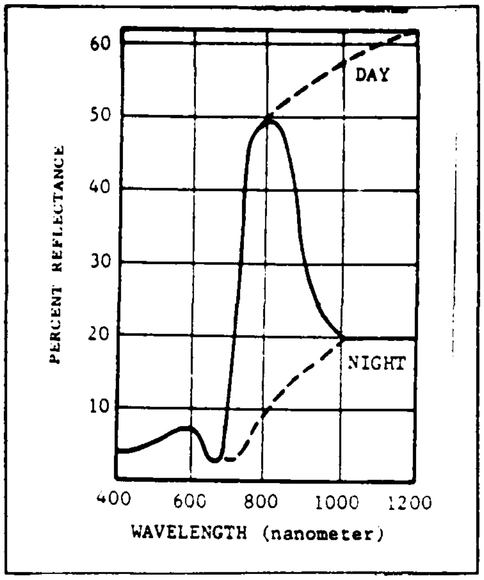


Figure 12 Relative contrast

of radiance itself. Of particular importance are the times during the day and night when the spectral radiances of different terrain features are identical, and when contrasts are therefore at a minimum. These times are called crossover times. Measurements of crossover times of various terrain features considered two by two have been made and these times are found to vary widely depending on the objects considered. Some examples are presented in figure 12.

4. Ground Target Radiation

From the standpoint of EO/IR Physics there can be no real distinction between targets and backgrounds. The interest of the moment is only the criterion for such classification since, particularly in the case of structures and terrain features, a target in one situation may well form part of the background in another. Under the passive surveillance system IR radiation from the ground target is due to the thermal emission and reflected solar energy. Most surface targets will be opaque or nearly so, and many objects of interest - such as roads and bridges having no internal heat supply - will be close to the ambient temperature.[Ref. 6:2-122] For example, since small surface area per unit mass usually reduce temperature fluctuations, concrete roads may be expected to be cooler by day and warmer by night than gravel or dirt roads. The recent presence of stationary vehicles or tents may be detected by a shadowed area. Ground temperature may remain different from the surroundings on the shadowed area for sometime after the vehicle or tent itself has been removed. In real time reconnaissance, the recognition and identification of such targets must depend, largely, upon evaluation of other factors such as shape, size, and context.[Ref. 6:p.2-122] Near ambient temperature (27 °C) blackbody emission is a maximum around 9.5 μm and the maximum variation of spectral radiance with temperature is in the region of 8 μm. For detection of targets of typical high emission, it is therefore good for suitable detector in the atmospheric window of 8 to 14 μm range. In this spectral range, the emissivity of most unpolished objects is quite high. For example, dirt has an emissivity of 90 to 95% while oxidized metals have emissivities of 75 to 85%. Buildings, vehicles and persons have an internal heat supply and may be



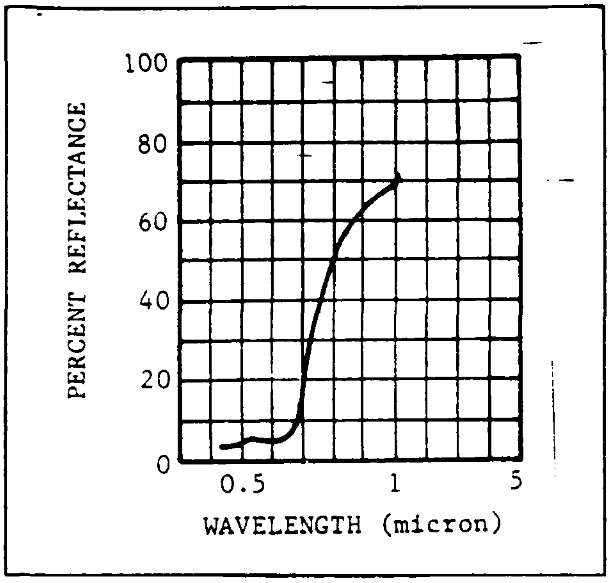


Figure 13 US army uniform cloth

Figure 14 Reflectance characteristics

much warmer than their surroundings. Also, part of tanks, trucks, EO/IR equipment cooling system and electric generator will remain hotter than their surroundings for several hours after use. In all cases, still, the emissivity must be considered. Special low-emissivity paints can greatly reduce the radiation from a hot surface of a vehicle or building. However, simultaneous camouflage against both visual and IR detection throughout the spectrum is extremely difficult. This applies not only to structures and vehicles but to personnel as well. Figure 13 shows an idealized reflectance signature for a camouflage uniform fabric. That provides protection against visual observations and near IR photographic detection by day, and sniperscope detection by night.[Ref. 6:p.2-123] Comparison with the reflectance signature of a typical US Army uniform cloth shown in Figure 14 is instructive. Compare the reflectance characteristics of human skin in Figure 15.

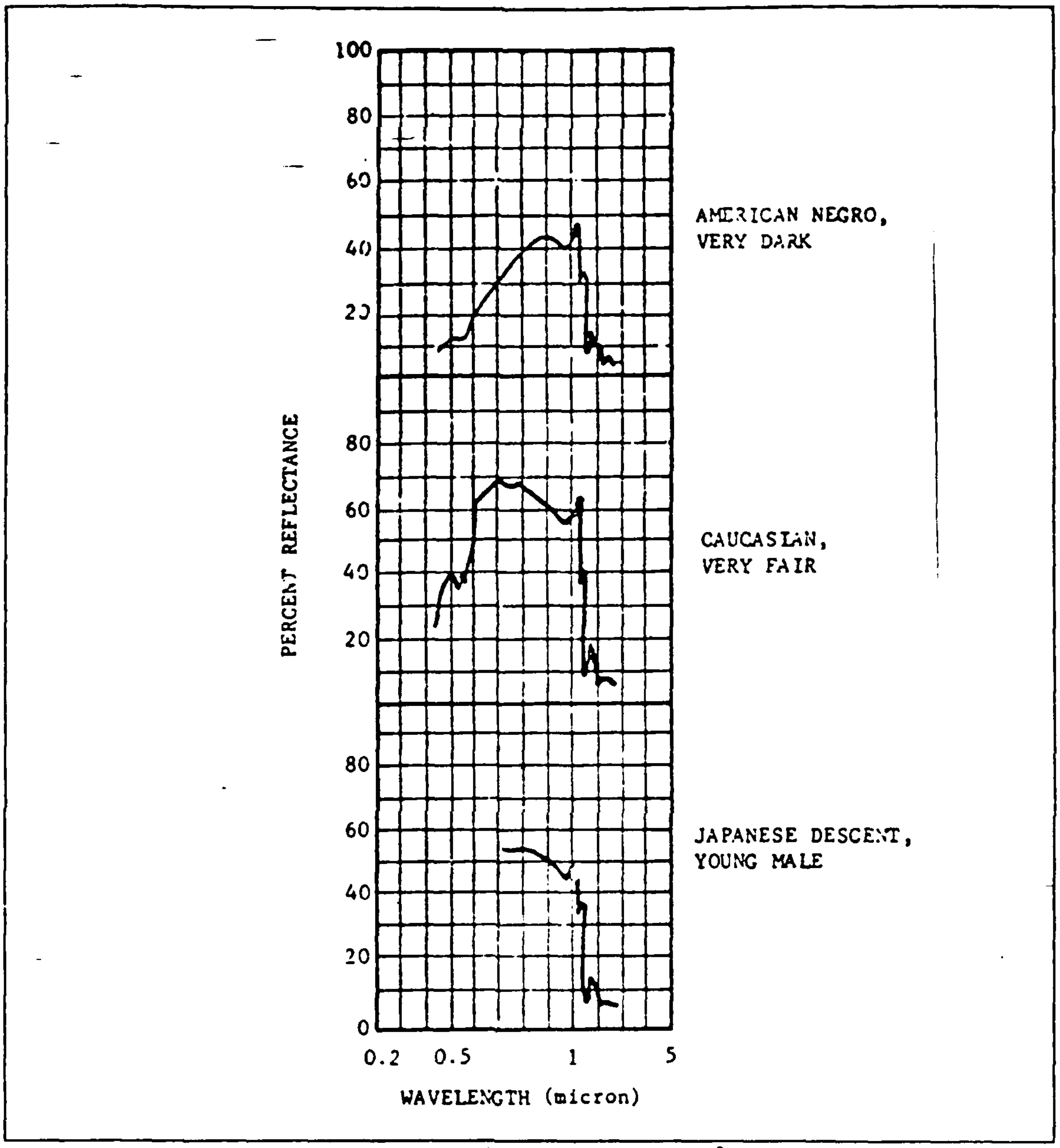


Figure 15 Reflectance characteristics of human skin

5. System Components

The various major components and techniques which enable active as well as passive systems to emit, focus, detect, and process EO/IR signals for any of a number of end uses are following.

a. Optical System

An optical system is a mathematical or geometrical construct which describes the relationship of object space to image space. It consist of lenses, mirrors and combinations of these elements. The incoming IR radiation is collected by the optical part of the system and delivered to the detector. Thus the optics are quite similar to a radar antenna used to receive echoes from a target. So, we must know what field of view of the optics must cover, the spectral region over which we will be using and a rough idea of the space into which they must fit.

The basic element of optical system for EO/IR equipment consists of one or more reflecting or refracting elements. All the elements are considered to be centered. This means, the centers of curvature of each of the surfaces all lie on the same straight line (*optical axis*). The conceptual picture of optical waves and lenses are shown in Figure 16.

b. Reticle

The reticle is an optical element used to modulate the incident flux with information that can be used to figure out the direction of the target. It might contain a set of cross hairs, precision scales to angularly circular grids. The incoming IR energy is focused onto the reticle. It is easy to process the IR radiation that is modulated by the reticle to change its DC nature to an AC signal. There are many possible reticle configurations. Each configuration has several advantages and disadvantages. However, reticle design can be developed in two broad classes. One class produces amplitude modulation (AM), which was the earliest configuration used. The other class produces

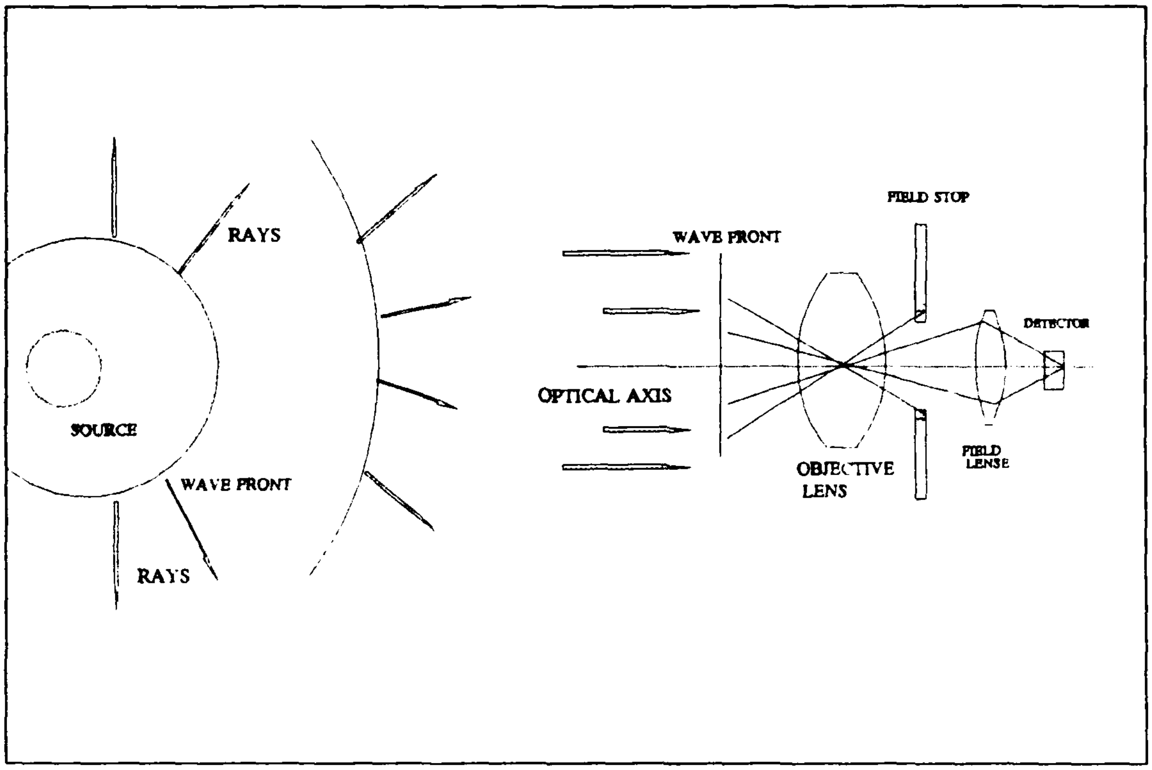


Figure 16 Wave front and lenses

frequency modulation (FM), which is used in all the most modern non-imaging sensors. Actually, the latest missile guidance system employs a combination of AM and FM, with the FM portion being the dominate feature.[Ref. 7:p.41] One advantage is that it is optimized for point source target. Extended area natural IR sources are rejected because of large target is not effectively transmitted through the reticle.

c. *Standard Modular Integrated System Concept*

In general, EO/IR equipment is designed to perform a very specific mission. The environment and the mission determine the characteristics and requirements the equipment involved has to meet. To optimize the performance of such equipment, special system parts and components are required and should be designed. It is generally known that such custom designed components are expensive over the whole operational life cycle of the equipment. Not only are the acquisition costs higher than for standard components but also the costs for logistic support and maintenance will be higher. Therefore a good balance between the use of standard and custom components can only be the result of careful consideration and precise analysis of the total EW system. The key idea of this kind of system is modular standardization. In the system design phase, the designers should be faced with couple of cross sectional experienced areas. And they can choose the best considerations based on these cross sectional areas. These areas can be the common standard check points to the new system development activities. In each project the designer should consider these check points and he will gain a useful experience from that project design. Experiences gained in several projects will teach him that standardization of specific components for EO/IR equipment. It is an advantage in designing and development of the equipment and will be beneficial to the users and operators. Lower operational life cost can be gathered from these kinds of considerations.

6. ECM Related Theory

The objective of the EO/IR Countermeasure is the reduction of threat effectiveness by prevention of detection, discrimination, identification, acquisition, lock-on, tracking, intercept and final kill with the least possible effect on mission objectives. For effective deployment of EO/IR Countermeasures, an optimum exploitation of combined active, passive and tactical countermeasures are required in many present and most future threat environments. Electrooptics and infrared countermeasures are yet in their infancy as compared with radar ECM, and they are likely to evolve only as threats from optical or IR sensors increase and as effective countermeasures technology evolves. Following are the several available countermeasures against EO/IR threats.

a. Passive Countermeasures

Passive countermeasures are those which are employed continuously and are not activated as a result of the presence of an attacker. The most generally employed passive countermeasures are contrast suppression, special contrast tailoring and pattern shaping. The primary objective of these techniques is to reduce or suppress the level of radiation from the defended platform to a low level so that the attacker cannot detect and/or lock on to his target until it is too late to attack.

b. Active Countermeasures

Active countermeasures are those countermeasures that either confuse or destroy the attacker's detection or guidance system. Flares, decoys, jammer and direct energy beams are all considered active countermeasures. Typical active countermeasures are following;

- Confusion by false target sources, such as flares and decoys,
- Masking by surrounding, foreground illumination etc,
- Intensity variation by power changes of prime and auxiliary sources,
- Jamming by false signal generation,
- Threat sensor degradation like photonic noise or saturation,
- Threat sensor negation by high intensity irradiance.

c. *Tactics*

Tactics can also apply to the ECM capability. There are six notable tactics in ECM environment;

- Exceed threat maneuver capabilities, take advantage of threat peculiarities, enhance or compliment effectiveness of other counter measures,
- Background selection to get such as contrast, reduction, false target and clutter advantage and threat sensor saturation (for example, in front of sun radiation),
- Maneuver to exceed threat dynamics to ensure optimum direction of shaped or unshaped radiation patterns about threat location,
- Maneuver to put a flare into threat line of sight or direction of jammer or illuminators,
- Hide in cloud or topographic conditions to reduce exposure time,
- Higher velocity to exceed threat dynamics.

For effective deployment of EO/IR countermeasures, an optimum exploitation of combined active, passive and tactical countermeasures is essential in many present and almost all future ground threat environments.

7. ESM Related Theory

The details of ESM systems are classified. However, it is to be assumed that a wide variety of systems have been developed specifically for ground stations, surface ships, large and small manned and unmanned aircraft, and missiles. ESM is based on methods of the target detection and target signatures. The basic activities of EO/IR ESM operations are intrusion detection, detect target or background, reconnaissance and surveillance. There are two basic detection methods; active and passive. The active detection method refers to the type of system that transmits an electromagnetic beam of rays and detects these rays when reflected from a target. In the passive detection method, the system detects the target radiation that emanates from the target itself. So the active ESM system needs an illuminating part, mirror or optical system and image converter. But the passive system only needs a optical part with sensitive elements and amplifier with indicator.

III. SYSTEM REQUIREMENTS FOR GROUND EO/IR SYSTEM

A. OPERATIONAL REQUIREMENTS

Systematic evaluation of five elements, mission requirements, functional requirements, targets, backgrounds and the effects of atmospheric transmission, establishes the basic framework within which systems are designed and optimized. The operation environment delineates the mission characteristics and objectives in such a manner as to permit the development of the functional requirements. The interrelationships among the various sensor parameters and performance parameters, and the constraints and objectives of the mission constitute the analytical and quantitative base for establishing a cost effective relationship. Thus, it is at this point early in system definition that mission profiles and overall objectives should be established.

1. ESM System

The basic operational requirements for an ESM system are sensitivity and high probability of intercept, adequate spectrum band coverage, emitter classification and identification, display system, direct ECM system and weapons control system, bearing or angle information, passive ranging capability, signal recording and good analysis, and system security. Along with these requirements, the most serious limitation posed by ESM system receivers has been their false alarm rate. Background radiation in the near IR spectral region is quite severe. As such, much work is being directed at the development of adequate background radiation discrimination techniques, because just as a high probability of intercept and warning is essential for survival, so is a low false alarm rate.

2. ECM System

The main operational requirements for an tactical ground ECM system are low vulnerability, system security and prior knowledge of the enemy's systems. Each will be taken up below.

a. Vulnerability

Vulnerability to an ECM system has four elements; susceptibility, accessibility, interceptibility and feasibility. First, susceptibility, implies the degree of system performance degradation introduced by a specific level of countermeasures over a feasible dynamic range. Second, accessibility refers to the possibility of applying an effective ECM technique to the susceptible points in the hostile sensor-weapon system along with the availability of a prior intelligence about the threat weapon's susceptible points. Third, interceptibility refers to the ability of an ECM operator to determine whether or not the enemy ESM system he intends to degrade is being used against him. Finally, feasibility refers to the technical, economic and tactical parameters that affect whether a particular ECM response is possible.

Feasibility is broken down into three areas and is the most important element of the vulnerability question. Feasibility's three time frames are (1) the current situation as a possible springboard for future projections, (2) the situation at the time of initial operational capability of the threat, and (3) the situation at the end life cycle.[Ref. 9:p.68]

The implicit requirement to field an ECM response within a defined period can have very important ramifications to a tactical operation because response time is usually the key to force survival. Timing is thus a very critical element of the feasibility of an intended electronic warfare response for the ground forces.

b. System Security

System security is not only for the ECM system but whole EW system. But special system security for ECM system is more important than many other systems. As we saw above, ESM, ECM and ECCM all act as a kind of series or chain. So if we can not secure our ECM system, we will be in vulnerable position to enemy ESM action or ECCM counteractions that neutralize our ECM activity.

System security is a complex combination of functions, processes, and resources. We can think of system security for a computer system, including security of open computer system access and computer virus protection. Open computer system security consist of security clearance of operator, equipment security, data security, and security of inter-computer communication. Protection against computer virus is another new kind of security activity. Computer virus is just a piece of code which hides itself inside the code of a program. It is very difficult to identify infected programs. In any event programs used to examine and heal other programs may themselves be infected, so the virus can spread as fast as it is eliminated. A virus can quickly cause catastrophic disruption of an EW computer system and its data networks.

c. *Prior Knowledge*

For effective ECM against the enemy system, first, we need intelligence (ESM), second, proper technique, and third, proper equipment. Analysis of threat capability and probable mission requirements analysis are the first steps of ECM activity. Only after these steps are taken we can apply jamming or deception techniques successfully. Without analysis of enemy strategy and tactics, we cannot achieve any ECM goals. So we need exact knowledge of threat strategy, tactics and equipment.

B. ENVIRONMENTAL REQUIREMENTS

Environmental requirements consist of various kind of geographical factors. We have to consider the entire Korean peninsula. Because of threat position, the northern part of Korean peninsula will be highlighted in this section.

North Korea has cold winters with average January temperatures of -8.1°C in Pyongyang and -17.8°C in Chunggangjin at the northern bend of the Yalu River. South Korea has relatively mild winters with average January temperatures of -4.4 °C in Seoul and 0°C in Pusan. All of Korea has hot, humid summers with average July and August temperatures in the 20°C and 27°C range. Summer temperatures are not so high, however, in the mountainous areas of North Korea and along the deep Sea of Japan.[Ref. 9:p.227] In the northern interior of the peninsula the high Kaema Plateau is divided by the headwaters of the Yalu and Tumen rivers so that, though called a plateau, it is structurally a land of mountains. Mount Paektu, the highest of these at 2744m, is an extinct volcano with a crater lake. All of Korea, except the high mountainous areas and the coastal zone along the Sea of Japan in northern Korea, has relatively warm moist summers, but there is great regional variation in winter temperatures. Bitterly cold winters are experienced in the northern interior with five months having average monthly temperatures below the freezing point; by way of contrast, the southern coast and Cheju and Ullung islands have average temperatures in January slightly above freezing. There is also a regional contrast between the small climatic influence of the Yellow Sea and the pronounced maritime effect of the Sea of Japan. The climatic variations in Korea greatly affect agricultural and land use patterns and practices. Floods caused by heavy or unseasonal rainfall can cause great hardship. Any delay in the spring and summer rains may result in drought conditions. Typhoons in late summer and early fall may cause severe damage to the buildings and antennas of the EW system. The geographical factors of Korean peninsula are listed in Appendix A.[Ref. 11:p.13-23]

C. HUMAN ENGINEERING REQUIREMENTS

Portability, man-machine interface and training factors can be regarded as human engineering requirements in this section.

First of all, we might impose an upper limit on weight to keep EO/IR device man-portable or at least easy to move between sites. Generally, such a requirement precludes beefing up structures and mounts to meet the rugged environmental requirements listed above. Space availability requirements might result in a package like a tank mounted search light. The system must be fit into a reserved space inside the sensor package ball or some space in the vehicle. Also there may not be enough room for the electronics equipment, which must be located elsewhere with a cable to the sensor. Increasing complex fire control systems for track vehicles generally means less space for the EO/IR tracking or target acquisition system. This is the case in the laser range-finder for the US Army's M-1 tank. They adjusted the laser range finder size for proper tank usage. Of course, miniaturization cannot be taken too far; one runs into performance, cost, or maintainability problems.

The design of the system must also consider the ease of training. The enlisted soldiers in Korea are very highly educated. They have at least a high school education. But we have to carefully consider both the background of Physics theory for the EO/IR system operator and the simplicity of the system operation. Soldiers who will operate a complex system like an EO/IR system, should have at least 14 years of educational background and at least one year of electronics. Most of the EO/IR theories are related to Physics. The EW officers and to some extent commanding officers who will employ the equipment also have to have a background of Physics or will require related additional training. Both a strong educational background combined with ease of operation will enhance system effectiveness. For a further discussions of particular human engineering and training characteristics are in next chapter.

IV. SYSTEM CHARACTERISTICS FOR GROUND EO/IR SYSTEM

A. OPERATIONAL CHARACTERISTICS

Army planners have to define missions, targets, doctrines, and techniques, as well as examine a wide number of hardware options attendant to survival against a sophisticated threat in the Forward Edge of Battle Area (FEBA). While there is little difficulty perceiving the nature of threats posed to enemy penetrating the FEBA, the countermeasures that must be employed, and the effects of control over the electromagnetic environment in a ground engagement are not as easily seen. For instance, ground force commanders do not operate with a few high skill technicians in an effort to launch a few complex and sophisticated weapons of great destructive power with their implicit needs for ranging, sensing and guidance. There are three generally accepted scenarios of EW utilization for ground force. First, Counter-Insurgency situations where friendly forces have air superiority and face a lightly equipped infiltrating enemy. Second, Division-on-Line battle situations against a sophisticated enemy with near or equal parity in the air. Finally, Mobile Defense situation where fronts are wide and battle areas range in depth from a few kilometers to hundred kilometers against a sophisticated enemy with air parity or superiority. These three scenarios require different mixes of EW equipment and doctrinal training for the EW operator, plus appropriate assessment of the tactical situations. Based on these scenarios, we can think of several operational characteristics for the tactical ground EO/IR system.

1. System Compatibility

With the expected proliferation of EO devices, and the concomitant increase of efforts, the insurance of compatible operation of the EO/IR devices with other friendly and neutral RF and EO/IR devices found in the same tactical environments is necessarily becoming a concern of various elements within the Defense Agency. Until recently, too little attention has been given the potential electromagnetic interactions between friendly EO/IR devices that could lead to degradation of system performance. Several possible theories have been discussed of a mechanism by which radiation in the optical portion of the electromagnetic spectrum might be coupled between an offending transmitter and a victim receiver, but these theories were rarely applied to the analysis of specific military EO/IR devices.[Ref. 12:p.47] The coupling of energy between friendly devices may occur via several principal coupling mechanism, and may be probable under certain tactical and atmospheric conditions.

2. Multi-purpose System Capability

Since existing EW equipment is extremely expensive and not cost effective in small numbers for smaller ground vehicles or different kinds of ships, a low cost alternative for ships, aircraft or ground systems in size and function is attractive. The solution for this problem is a module related family of EW systems for the defense of air, sea and ground systems. The design of the system allows tailoring of superior EW capabilities for different classes of purpose. And the standard system for each module must be stated by the defense system engineer. The system must also be evaluated for simplicity and compactness, as well as maintainability.

3. System Engineering

In the point of system engineering, the system has to have combat proven characteristics. In real combat, we can not use non-tested equipment. But it is very hard to test equipment in a combat situation at peace time. So we have to develop possible other tools for testing combat situation, such as proven equipment from combat simulation, field tested equipment. If there are equipment already proved in real combat, that equipment should make the best systems. But in this case we have to consider the situation of the combat and geographical condition very carefully.

Along with this capability, the system must have high reliability, maintainability, proper man-machine interface conditions, low cost compared to an RF system and the finally and the module or equipment is already a developed system. These characteristics stated in this section are not only applied in the EO/IR system but also in any EW system. And these will make more effective tactical system.

B. ENVIRONMENTAL CHARACTERISTICS

Military EO/IR systems are required to meet specifications over a wide range of ambient conditions after exposure to severe mechanical or thermal loading. A typical military laser's operating temperatures range between -31.7°C to +68.3°C (+62.8°C with sun loading) in standard condition. Storage temperatures of -45.6°C to +71.1°C are also standard.[Ref. 13:p.55] These conditions are acceptable to the EO/IR system. The system also has some product specification about the icing, salt fog, fungus resistance, reliability, standardization, cost, system integration, transportability, temperature shock, rain, snow, and severe storms. Some designs must withstand immersion in several meters of water

TABLE 1 OPERATIONAL CHARACTERISTICS

CHARACTERISTIC	SYSTEM
SYSTEM COMPATIBILITY	WITH FRIENDLY EO/IR SYSTEM WITH RF SYSTEM
MULTI-PURPOSE SYSTEM CAPABILITY	AIRBORNE SYSTEM SHIP BOARD SYSTEM SUBMARINE SUPPORT SYSTEM GROUND SYSTEM STRATEGIC SYSTEM
SYSTEM ENGINEERING	COMBAT PROVEN EQUIPMENT HIGH RELIABILITY AND MAINTAINABILITY MAN-MACHINE INTERFACE LOW COST NON DEVELOPMENTAL ITEMS

for a couple of hours. Some of the toughest environmental conditions concern shocks or vibration that the units might undergo in operation and transportation. Generally the terrain condition of Korean Peninsula is very rough. The four distinct seasons make tougher conditions than in most of the western hemisphere. We have many hills, rivers, and mountains. Specially, most of the areas in the northern part of Korea are mountainous. So we have to worry about the dropping of equipment from a height greater than 1 meter onto rocks or concrete. Simulated parachute drop, rail impact, or

TABLE 2 ENVIRONMENTAL CHARACTERISTICS

CHARACTERISTICS	STANDARD
OPERATION TEMPERATURE	-31.9°C - +68.3°C
STORAGE TEMPERATURE	-45.6°C - +71.0°C
ENDURANCE	ICING, SALT-FOG, FUNGUS, TEMPERATURE-SHOCK, RAIN, SNOW, STORM AND WATER-PROOF
DROPPING	1 METER ON CONCRETE
SHOCK	100 grams WITH 5 milliseconds DURATION
WATER IMMERSION	SEVERAL HOURS

gun shocks can reach accelerations of more than 100g inside of 5 milliseconds duration. Besides all this abuse, the units must meet the specified technical requirements with no adjustments, alignments, or tweaks. Further, in the view of the apparent North Korea emphasis on night operations, night interdiction and battled support missions must be assumed. And we must prepare for fog, cloud, rain, snow and other severe weather operation. An EO/IR system works with very limited capability under these conditions.

C. HUMAN ENGINEERING CHARACTERISTICS

Human engineering characteristics are divided in to two categories; man-machine interaction and training. The ability to quickly and easily display geographical and tactical data in various graphical forms and perspectives is a technology that has come of age. Together with the use of icons, mouse and touch screen technology, graphical displays will find increasing use within decision support systems in representing EW situation assessments as well as planning and resource allocation. And the use of voice to control the interactive graphical display, to query the knowledge base and to provide data reports to the decision support system is a major technological means to the man-machine interface techniques. Along with these techniques, we have to be concerned about the specific equipment conditions. Human factor data should be collected using three different methods: questionnaires and interviews for the EO/IR equipment operators, measurement of hardware and experiment. In questionnaires, we have to look at five different areas of the system: individual equipment components, work space, environment, safety, and general procedure. The measurements consist of determinations of knob and dial size, as well as configuration and style. In experiments, we have to deal with the capability in chemical warfare operations or winter time for the portable system. In these cases, we require gloves. Wearing such gloves would interfere with manual dexterity and lower the performance of the operations. Any performance degradation caused by the use of gloves would also seem to be exacerbated by the vibration and movement of the vehicle while it was field operation. All data should be gathered with respect to individual hardware components, work space and overall equipment configuration, environment, safety, operating procedures. The data should be analyzed to determine whether the operator is having problems with the system and whether the hardware design meets standard military specifications. Problems encountered have to be analyzed and

TABLE 3 HUMAN ENGINEERING CHARACTERISTICS

CHARACTERISTICS	CONDITION
MAN-MACHINE INTERFACE	GRAPHICAL DISPLAY PULL-DOWN MENU AND MOUSE TOUCH SCREEN DISPLAY PROPER DATABASE HUMAN FACTOR TESTING
TRAINING	SIMULATOR DIFFERENT LEVELS OF TRAINING TRAINING BASED ON PHYSICS THEORY USING PERSONNEL COMPUTER PROPER TRAINING PROGRAM

discussed with the operators and system engineers to determine how they can best be solved.

Apparently there is not enough time for training crews. We hardly have time to build the system, let alone a simulator or training device to teach operators how to use them. We could spend more money for more black boxes, while the majority of our EW system operators do not even know how to operate the EW equipment they already have. Equipment is not that difficult to teach and understand. We must simply have our priorities in the right place.

Several levels of training have to be developed for the operators, maintenance personnel, EW officers, and commanding officers. Many pieces of equipment such as personnel computers and EW simulators can be used for this training. Since the advent of the personal computer and the proliferation of software, we have had to develop many advocates of desk top trainers and rightly so. They are a definite asset in the classroom and for personalized individual training. These can be used to teach basic switchology and decision making processes for normal combat or emergency procedures. But they generally do not provide the integration and synergism of systems and actual battle field. This must be accomplished by EW field training. EW field training is not easy. We have to be concerned about commercial broadcasting system, air traffic control and security. Field training for EO/IR equipment costs a lot of money. So we have to develop good simulators for EW system training. There are no adequate training devices available for overall EW training. Operators may be able to learn EW swichology and procedures on a PC, but this must be followed with a training device that can integrate initial maneuvers with countermeasures reactions to simulated threats, and there must be a provision for repetitive training so that EW responses become the automatic response.

D. EO/IR SYSTEM TEST AND EVALUATION

1. General

The objectives of a test program are to provide confidence and assistance to the system engineer that the system meets operational objectives, assurance to the designer that his design is fabricated by his instructions, and proof to the customer that the delivered article meets his requirements.[Ref. 6:p.5-67] The heart of the test and evaluation plan is a definition of the flow of material, parts, subassemblies, and assemblies through a succession of evaluation and test operations to the final assembly and acceptance of the end item, and a description of each evaluation and test operation. The complete test and evaluation program must span the entire processes from breadboard development through prototype manufacture to field evaluation, and then to production quality assurance. In this paper we will be concerned only for the test and evaluation in the system design phase.

2. Optical Elements

The major considerations in the test of individual optical elements are material quality, surface quality(finish), surface accuracy(curvature), and complete geometry. We have to have certain standards for these elements and proper facilities. Most of the standard test conditions in Korea are based on the foreign standard conditions. But the test conditions of certain equipment are totally different in certain geographical factors. So we must develop these standard conditions and apply these conditions to our standard equipment.

3. Optical Material

Generally, optical materials for lenses, prisms, mirrors, and other elements are bought in rough blanks for fabrication into the required forms. While gross inclusions and flaws are easily detectable in transparent material, they may be hidden in opaque materials such as germanium and silicon commonly used for IR elements. Other qualities, such as variations in spectral transmittance, order of refraction, and low angle scattering, require tests of specially prepared samples and frequently yield inconclusive results due to variations between and within batches.[Ref. 6:p.5-68] Sometimes the presence of defects are not detected until the complete optical instruments are assembled and tested. So the most practical and economic courses in many circumstances may be to get premium grade optical materials from a recognized supplier, and be prepared to reject some percentage of completed elements at an optical system test level. Surface accuracy is conventionally specified in the number of rings, and distortion of the rings, in an interferometric comparison of the element in close contact with a standard test plate in the presence of a standard monochromatic light source such as a sodium or mercury vapor lamp.[Ref. 6:p.5-69] This test is simple, but the reliability is dependent on the accuracy of the test plate that is determined by direct opto-mechanical measurement under certain laboratory conditions.

4. Optical Filters And Coating

The typical IR system needs the specially coated optical elements for selective transmission or reflection. Specially coated lenses and mirrors cannot be tested normally. They need certain test tools for transmittance and reflectance because of curvature and size of that element. It is general practice , therefore, to select "witness samples" for coating that are then subjected to testing with a spectrophotometer.[Ref. 6:p.5-69] But the typical filter is deposited on the flat substrate and can be directly measured. Specially stated critical bandpass or cutoff characteristics will help to ensure that certain spectral properties with temperature are considered. This is particularly true when the end item is to be used at extreme temperature and terrain conditions.

V. FUTURE TRENDS OF TACTICAL EO/IR SYSTEM FOR GROUND FORCES

A. SOLUTION OF SMIS

The Standard Modular Integrated System(SMIS) is based on the modular concept. All conceivable functions included in the system's design objectives have been integrated into carefully studied *integrated standard functional blocks.* These blocks are in turn made up of a certain number of individual integrated modules, which are identical in size. Since they have been standardized both mechanically and electrically, being fitted with standard electrical edge connections, the integrated modules can easily be exchanged without requiring further adjustments. The only requirement is for the modules forming one assembly to be mechanically and electrically interconnected. This is done by means of a special equipment rack which houses all the modules, and contains the appropriate electrical interconnections. All control and display functions are provided in separate housings remote from the rack. These units, together with the different modules in the rack, constitute a complete system. The use of SMIS reduces the problems of interfacing different units, and provides an additional argument in favor of a system concept which provides both technical and logistic standardization, despite the diversity of equipment. SMIS has many advantages, such as if the system is independent equipment.it has reduced vehicle RCS because it has fewer receivers, signal processors and detector location. And if we can achieve SMIS, we can get aerodynamic advantage as well as faster ESM and ECM response time. Figure 17 shows application of coordinated future EW.

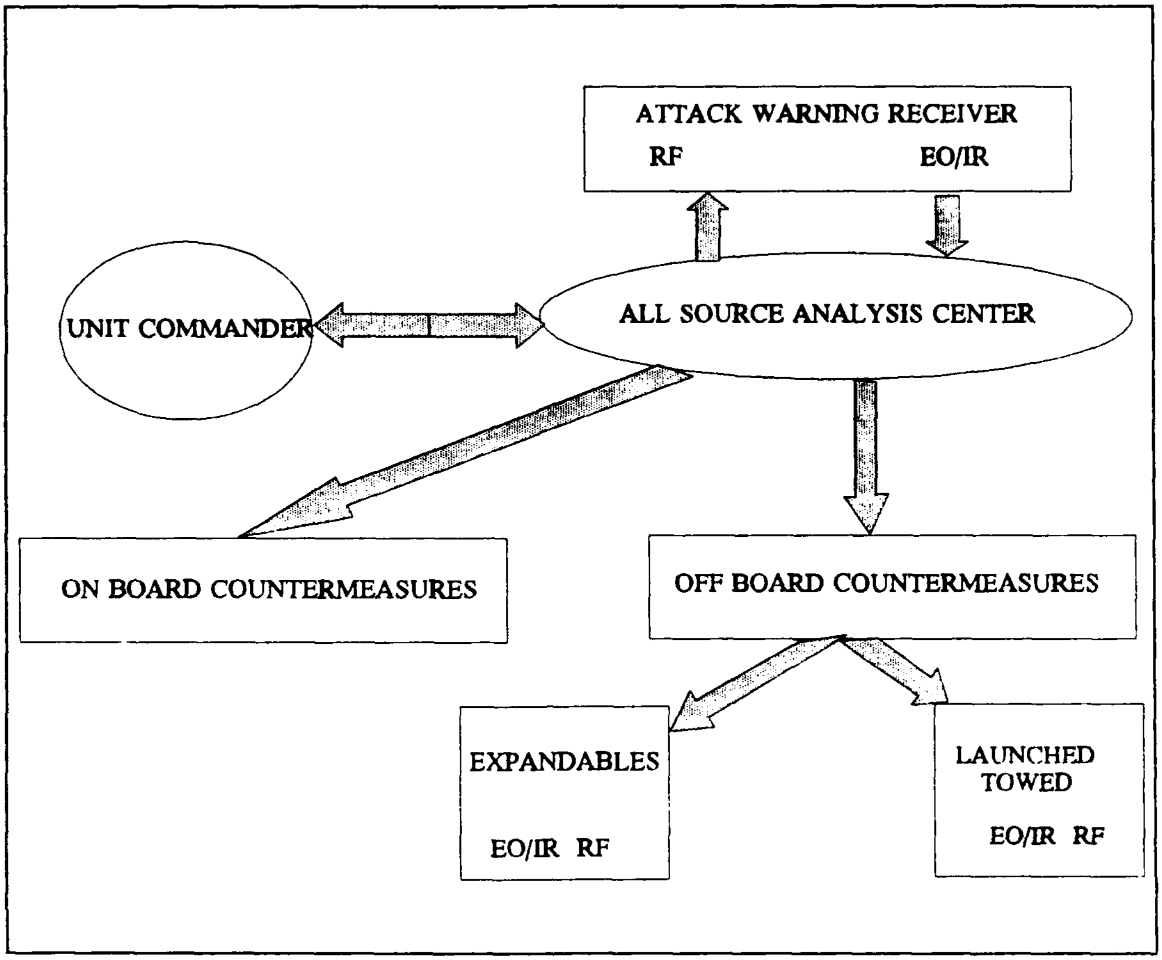


Figure 17 Coordinate future EW system

B. APPLICATION OF AI AND ROBOTICS

Artificial intelligence (AI) is the getting of computers to do things that seem to be intelligent. This means that more intelligent computers can be more helpful to us, better able to respond to our needs and wants, and more clever about satisfying them. Artificial intelligence includes:

- Getting computers to communicate with us in human languages like English, either by printing on a computer terminal, understanding things we type on a computer terminal, generating speech, or understanding our speech (*natural language*);

- Getting computers to remember complicated interrelated facts, and draw conclusions from them (*inference*);
- Getting computers to plan sequences of actions to accomplish goals (*planning*);
- Getting computers to offer us advice based on complicated rules for various situations (*expert system*);
- Getting computers to look through cameras and see what's there (*vision*);
- Getting computers to move themselves and objects around in the real world (*robotics*).[Ref. 14:p.2]

The AI/Robotics concept of the EW could permit timely and responsive countermeasures operations to be started - with an adaptive EW control system for flexibility. In general, AI could be applied to EW systems in the area of adaptive properties, decision-making capability, processing *exotic* signals and enhancing the ability to prioritized the EW threats.[Ref. 15:p.46] Selected aspect of AI can aid in the selection of appropriate countermeasures techniques by helping in the management of available resources, including the analysis of real time sensor data for emitter identification, emitter location, threat identification, prioritization, technique selection, direction, frequency, power and tactical coordination for active system. Future EW operation with AI application is in Figure 18.

C. COMPUTER PROTECTION

Military electronic systems include a wide variety of sensors, control systems, communications and electronic warfare equipment. Sensors include radar, EO/IR systems and acoustic systems, and fill many critical functions including monitoring system operation and target development.

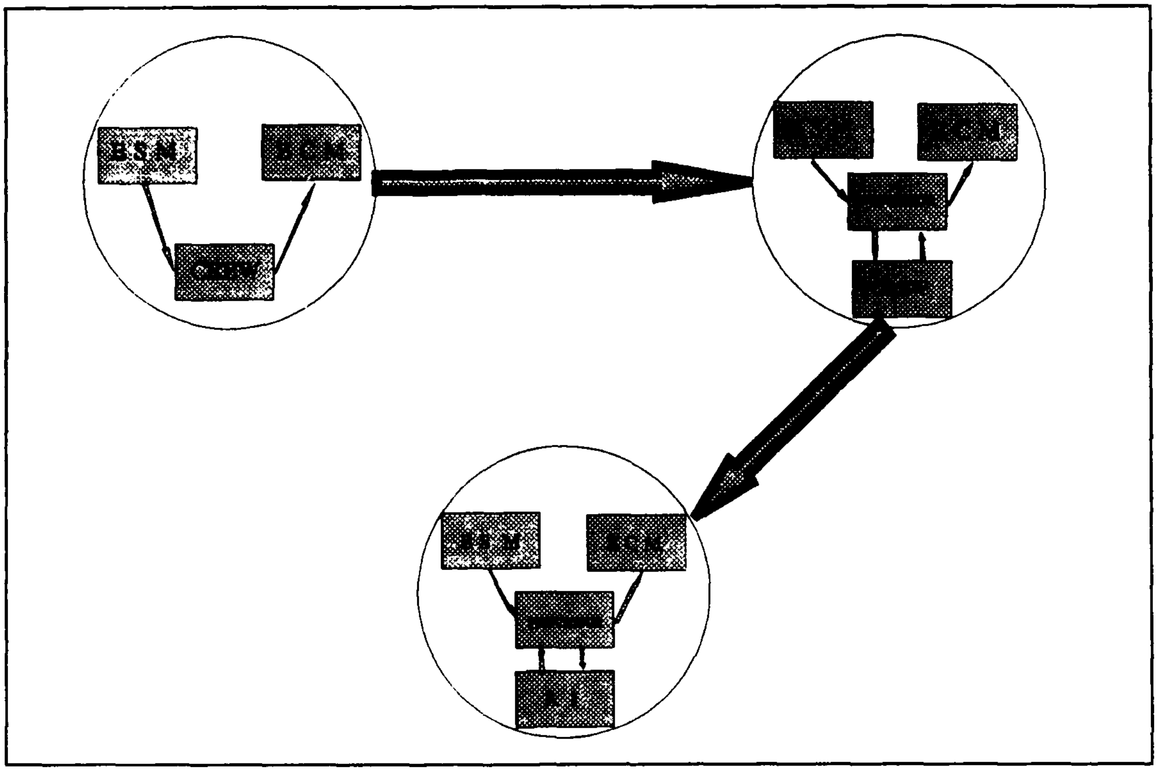


Figure 18 Future EW operation with AI application

A key development factor for these military electronic systems is usage of high speed computers. This makes possible a new form of electronic warfare by the electronic insertion of harmful computer virus micro-code into a victim electronic system. Protection could be called computer virus countermeasures(CVCM).

Computer viruses once existed only in theory. The concept refers to computer code that can, like biological viruses, both infect another program, and reproduce itself spread within a host computer system. TABLE 4 illustrates the relationship among CVCM and traditional forms of ECM. Previously, ECM systems functioned by targeting the receiver elements in electronic system. By contrast, CVCM operate by targeting the victim system's processor.[Ref. 16:p.75] Compute virus countermeasure is uniquely

TABLE 4 COMPARISON OF CVCM TO TRADITIONAL ECM

TYPE	EXAMPLE	TARGET	EFFECT
NOISE JAMMING	SPOT, BARRAGE COMBINATION & OTHER PATTERN	RECEIVER	DISRUPTION OF LINK
DECEPTION JAMMING	SWITCH-TONE CAPTURE PULSE-OFF TECHNIQUES	RECEIVE AND RF PROCESSOR	SYSTEM IS UNAWARE AND DECEIVED
CVCM	*TO BE DECLARED*	*PROCESSOR*	*SYSTEM IS UNAWARE AND DECEIVED*

qualified to disrupt tactical EW operations. Because they continue their operation after the time of the jamming transmission, Computer virus countermeasure effects are considerably extended in time compared with traditional ECM, whose effects begin and end with the jamming transmission. CVCM is contagious. It can spread from system to system and from user to user, giving the virus widespread effects. As with real viruses which spread from person to person, there must be same form of contact between the two computers such as a modem or other connection like a local area network (LAN) or the exchange of programs by way of floppy diskettes.

A typical modern EO/IR system uses a very complex computer system. Strategic systems use a very high speed computer system. So we have to consider CVCM techniques for EO/IR systems. The main point is that implementing an effective CVCM protection strategy requires effective hardware and software design as well as disciplined operations. Right now the injection method of computer virus in to the system is a kind of sabotage action. But in the future an enemy will develop a lot of other methods to inject computer virus to our system.

VI. CONCLUSION/RECOMMENDATION

Many military experts agree that a conflict in the Korean Peninsula will be characterized by the massive employment of 3-dimensional forces (air, sea, and ground forces). Most experts also agree that the outcome will depend on mobility, speed, local numerical superiority and combined operations in which aircraft, firepower and other means of support will play key roles. In a situation of this type, it will be vital for us to get and process our intelligence concerning enemy force deployment and intention in something close to real time. This must be done in depth to plan and implement, deter or delay enemy action. With this objective in mind, EO/IR surveillance system will be a primary tool of surveillance and effective attack on the enemy's Command, Control, Communication and Intelligence (C^3I) system. From the aspect of electronic warfare, one of the most important advantages of EO/IR systems is that of a totally passive detection system. So we have to redefine electronic warfare to include all actions conducted in the entire electromagnetic spectrum to intercept, analyze, manipulate, or suppress enemy use of the spectrum as well as to protect friendly use of the spectrum from similar attack by an enemy.

Clearly the EO/IR-guided weapons are becoming increasingly prevalent and capable in today's military scene. The EO/IR sensor technology produces the ideal weapon in a world where the complexity of warfare is dramatically changing. The integration of infrared and microwave radar into a combined system for precision-tracking and fire control application is a natural development. The microwave radar will measure the range to the target and enhance the field of view, whereas the infrared system with its much finer angular discrimination capability will be used for precise angular tracking. At the time of weapons acquisition, we have to be concerned with the geographical point of view and climate. For Republic of Korea, one of the major issues for the system is portability. And finally, we should have a special military EW Officer's training course for basic EO/IR related Physics theory and the same for enlisted personnel. These will help us to win in the future complex electronic warfare environment.

APPENDIX A. AIRCRAFT LOSS SUMMARY: 1977 - 1985

EVENT	DATE	COMBATANTS	GUNFIRE	RF AAM-SAM	IR AAM-SAM	TOTAL
Gulf of Sidra	1981	Libya vs US Navy	0	0	Libyan-2, AIM-9L	2
Falklands	1982	UK vs Argentina	0	0	ARG: 1-2 by Stinger, 27 by 9L	28 to 29
Lebanon	1982	Syria vs Israel	Syria: 1	Syria 5+ By Sparrow	Israel: 1? SAM Syria: 89 by AIM-9G/L PYTHON	96+
Kamchatka	1983	Korea vs USSR	0	0	Korea: 1 B-747(KAL-007) by AA-3 or SS-S	
Afghanistan	1979 To date	Afghan Rebels vs USSR	USSR: Several Helos Claimed	Unlikely	USSR: Several Helos and Attack A/C Claimed	Several Claimed
Persian Gulf	1984	Saudi Arabia vs Iran	0	Iran: 2 by Sparrow	0	2
Iraq/Iran	1980-1985		Unknown	Unknown	Iran: 10-20 by Magic 1	10 to 20
Granada	1983	USA vs Cuba	USA: 7 to 9 Helos	0	0	7 to 9
Total			8+ to 10+ (5.6%)	7+ (4.4%)	135+ to 146+ (90%)	150+ to 163+ (100%)

APPENDIX B. GEOGRAPHICAL FACTORS OF KOREA

Korea is commonly divided into two areas along the boundary connecting Seoul and Wonsan, the so-called Chugaryong Rift. However, it is sometimes divided into three sectors: the northern sector, the southern sector and the central sector. The major portion of the country is mountainous and only 20 % of the country is flat land. Korea is counted as one of the rare mountainous countries in the world. Larger portion of the crust of Korean land is composed of paleozoic and neozoic layers with the sea layer confined to only a small part of land. There have been no major adjustments in crust formations since the Jurassic and Tertiary Periods, save for some volcanic activities during the Tertiary and Quaternary. Therefore, the features of the land are characterized by flat hills without any notable undulations. Though the eastern part of the country is still in its prime due to its exposure to erosion for many years, the rest of the land is quite worn off. Korean hills lack vertical carriage and, for the most part, are spread out horizontally. The crests are mostly shaped like plateaux and their peaks constitute monadnocks created as a result of long years of erosion. There is no peak in the land that exceeds 3,000 meters in height. The average for the Kaema, highest plateau in the country, is only 1,500 meters. Mount Paektu, the highest peak, is 2,744 meters high - the average peak for the country as a whole is 482 meters high. From the stand point of geographical features, Korea is a chain of hills stretching out from Asian Continent. Between these hills run winding rivers and meandering streams making for beautiful sceneries through out the land. The climate is determined mainly by such factors as monsoon, latitudinal position, terrain and currents washed on the coastlines. The country spans 9 degrees latitude and the level of terrain is higher in the north than in the south. Due to these geographical factors, the nearer the northern frontier, the lower the fall in average temperature. The average through the year is 13°C along the southern coast while it drops as low as 10°C and 8°C over the middle land and northern zones of climate respectively. The west coast is open to continental Asia and is vulnerable to the influence of the cool monsoons in any season of the year. The east coast, on the other hand, is separated from the west by the steep Chungnyang mountains that keep it from the monsoons of the northwest and moderate the winds from the same direction; it is further affected by the warm currents of the Eastern or Sea of Japan. Thus, it is about 2°C warmer in the east than in the west.

Difference in temperature are least conspicuous during summer. The average temperature in August in the lower area of the east coast, which is affected by the warm currents, is about 25°C while it falls down to about 21°C in the northern part of the northeastern coast and the Kaema Plateau. The average maximum temperature throughout the whole land is generally over 35°C and the cities of Wonsan and Taegu have respectively registered the record-high temperatures of 39°6'C and 40°C. The hottest period of the year lasts about one month, starting from early August. The temperature then is close to the tropical zone and much hotter in the midland and the areas below than in the rest of the country. The area around Taegu is the hottest region in Korea.

The outstanding feature of winter is the clear temperature difference between north and south. The lowest temperatures along the southern coast, in the midland and on the Kaema Plateau up in the north are respectively -15°C, -20°C and -30°C or colder. The northern frontier town of Chunggangjin once claimed the lowest temperature of -43°6'C. The town and its vicinity is known to be the coldest spot in Korea. In winter, the mountains and fields are snow-clad and rivers are frozen. The winter lasts for six months in the northernmost areas while it lasts for only three months in the southern provinces. The undoubted cold of the Korean winter, however, is not so unbearable because three days of successive cold are invariably followed by four successive warmer days as the high atmospheric pressures of the continent alternate in a well-high regular pattern of progression and retrogression.

The average annual precipitation of rain in Korea is 500 - 1,500 mm. More than half of the land registers an annual average precipitation of 800 - 1,000 mm, two times that of the neighboring mainland of China and half the amount usually registered in Japan. The six months from October to March is the dry period; April - September is the wet period. The rainfall during the wet period corresponds to the total annual precipitation, while the wet season of June - August draws almost 50 to 60% of the total. More rain falls in the western part of the land than in the eastern. Among the areas that draw most rain are the southern part of Kyongsang Namdo, the eastern part of Cholla Pukdo, the basins of Han and Kuryong Rivers. All of them register more than 1,300 mm. The area of the Samjin River estuary is known as the wettest spot with 1,500mm of rainfall. Extreme northwestern or northeastern areas draw very little rain, registering only 700 - 900 mm a year, while the areas in the upper reaches of River Tumen register the scantiest rainfall with 500 mm.

There are eight different climatic zones in Korea. The factors that determine the

TABLE A-1 CLIMATIC ZONES

NAME	TEMPERATURE(°C)		PRECIPITATION (mm)
	WINTER	SUMMER	
Archipelago Zone Kyongsang Namdo. Cholla Namdo. Cheju-do.	1-2 (4 in Cheju-do)	22-26 (23 in Cheju-do)	1100-1400
Eastern Sea Zone Eastern coast south of Mt. Kumgang. Kyongsang Pukdo. Kyongsang Namdo.	1.5-2	24-26	950-1250 (1600 in Ullung)
Eastern Korea Bay Zone Southern part of Hamgyong Namdo. Eastern coast north of Mt. Kumgang.	4-5	22-24	900-1300
Southwest Provinces Zone Cholla Pukdo. Southern half of Chungchong Namdo. Sandwitched between Chungnyong and Noryong mountains.	2-4	26	1100-1300
Central Zone Kyonggi-do. Western part of Kangwon-do, Chungchong Pukdo. Hwanghae-do. Northern half of Chungchong Namdo.	8-12	25-26	1200
Hwangpyong Provinces Zone Northern part of Hwanghae-do. Southern part of Pyongan Namdo. South of Taedong river.	8-11	23-24	800-1200
Pyongan Provinces Zone Pyongan Pukdo. Pyongan Namdo. North of Taedong river.	7-15	22-24	1000-1300
Kaema Plateau Zone Northeastern provinces, excluding southern part of Hamgyong Namdo.	9-20	17-19	700-800

division of zones are temperature. precipitation, humidity and terrain. The eight zones are listed in TABLE A-1.

Character of Korean soil is affected by the climate to a great extant. The climate is characterized by the fact that the year has its spells of dry and wet seasons and that most of the rain falls during the three months of June, July and August. Furthermore, slopes in Korea are generally gentle and the weathered surface of soil is apt to be washed

TABLE A-2 AVERAGE TEMPERATURE AND PRECIPITATIONS OF MAJOR CITIES

CITY	TEMPERATURE(°C)					PRECIPITATION			
	Jan	Jul	Year	High	Low	Year	Jul	Aug	Wet days
Songjin	-5.8	22.1	8.1	37.5	-24.6	703	103	163	105
Chungkangjin	-2.1	21.6	3.7	38.6	-43.1	818	176	183	131
Sinuiju	-9.8	24.1	8.7	36.9	-27.7	818	176	183	100
Wonsan	-3.8	23.8	10.3	39.6	-21.9	1328	270	320	117
Pyongyang	-8.2	24.4	9.3	37.2	-28.5	941	243	232	108
Seoul	-4.9	25.5	11.0	38.2	-23.1	1246	366	250	112
Incheon	-3.9	25.0	10.8	38.9	-21.0	1043	286	206	105
Taegu	-1.7	26.0	12.5	40.0	-20.0	970	299	157	90
Chonju	-2.0	26.0	12.2	38.2	-17.8	1233	299	249	125
Kwangju	-1.1	25.4	13.9	37.6	-19.4	1243	261	219	128
Pusan	-1.9	25.6	13.6	36.0	-14.0	1399	279	179	101
Mokpo	0.9	26.1	13.2	37.0	-14.0	1065	197	166	128
Cheju	4.6	25.9	13.3	37.5	-50.7	1382	206	216	141

away by torrential rainfalls during the rainy season. The average temperature and precipitations of major cities are listed in TABLE A-2.

APPENDIX C. DEFINITIONS OF EO/IR RELATED TERMS

AM (Amplitude Modulation) - Variation in the amplitude of an alternating current or radio wave. May be introduced (1) deliberately to convey information or achieve a desired end or (2) as a result of equipment imperfections, or (3) Through natural causes.

Analog device - Quantities or representations that are variable over a continuous range are referred to as analog. An analog signal is usually a voltage (or current) that is proportional to some physical quantity of interest. For example, imagine an electric thermometer that gives out a voltage that is proportional to the temperature. An analog device uses this analog signal. It is a mechanical, electromagnetic, or electrical device (or circuit) whose response to an input is analogous to a desired mathematical operation - such as addition, multiplication, etc. - or to particular combination of such operations.

Angle of incidence - Angle at which the wave fronts of a electromagnetic wave, such as that transmitted by a radar, strike the ground - hence also the angle between the normal to the earth's surface (local vertical in the case of flat terrain) and the wave's direction of propagation.

Atmospheric refraction - Refraction (bending) occurring when electromagnetic radiation propagates through the atmosphere. This effect is due to the gradual decrease in the dielectric constant of the atmosphere with altitude. This decrease causes the speed of light to be a tiny bit slower at low altitudes than at higher altitudes, hence results in the path of the radiation bending downward slightly, enabling a radar to see slightly beyond the horizon.

AGC (Automatic Gain Control) - The continuous adjustment of the gain of a receiver or an amplifier so as to keep the average level of the output more or less constant.

Bandpass - The band of frequencies within which the frequency of any input to a given circuit or system may lie without there being any significant reduction (e.g., no more than 50%) in the power output relative to the output that would be produced by the same signal if its frequency were centered in the band.

Bandwidth - (1) The width of the band of frequencies passed by a filter or an electrical, electromagnetic, or mechanical system. (2) The band of frequencies occupied by the central lobe of the spectrum of an alternating current signal. Bandwidth is usually defined so that it includes the portion lying between the points at which the power has dropped to half that at the center of the band.

Chaff - Thin, light strips of foil or metalized fiber that may be scattered in the air to hide targets or otherwise confound the operation os an enemy's radar. The length of the strips as usually made equal to one half of the wavelength employed by the radars the chaff is to be used against so as to maximize the chaff's radar cross section.

Decibel - A logarithmic unit used to express power ratio. One decibel equals $10\log_{10}(P_2/P_1)$. Decibels are also used to express the absolute values of certain quantities whose values may be vary over a wide range, such as power, radar cross section, and antenna gain. In this case, the decibel value express as the quantity in ratio to a given reference value.

Detection - The process of determining the presence of a target.

Diffraction - The phenomenon which causes light passing through a small hole to spread and be surrounded by progressively weaker rings of light. The same phenomenon is what causes the beam of a directional antenna to spread and be surrounded by sidelobes. Diffraction is explained by considering that every point on a wave front of an electromagnetic wave acts like an independent radiator.

Digital - The term digital is used to define a quantity that exists at discrete states, or levels, rather than over a continuously variable range. Usually, the total possible number of levels is a power of 2, such as 2, 4, 8, 16 and so on.

Electric field - Field of force produced by an electric charge or a changing magnetic field. Has both a direction and magnitude. May be visualized as the force exerted on a tiny charged particle placed in the field.

Electromagnetic wave - Wave that is propagated by the mutual interaction of electric and magnetic fields. Radiant heat, light, and radio waves are electromagnetic waves.

Electrooptics (EO) - The branch of physics that deals with the influence of an electric field on the optical properties of matter, especially in crystalline form. These properties include transmission, emission and absorption of light. Electrooptics has become increasingly important in recent years, with the advent of laser, optical fibers and optical communications in general.

Frequency - Number of cycles per second which a pure unmodulated sine wave completes per second.

FM (Frequency Modulation) - Variation of the frequency of an AC signal or radio wave. May be deliberately produced to convey information or accomplish a given end, such as range measurement, or be the result of equipment imperfections or natural causes.

Infrared systems (IR systems) - Systems depending on the detection of IR radiations of target. IR systems are used in missile guidance, fire control, bombing, and reconnaissance.

Jammer - An electronic device which intentionally introduces unwanted signals into enemy communications, radars or EO/IR equipment for the purpose of denying information.

Jamming - The transmission of electromagnetic signals for the purpose of interfering with enemy electromagnetic activities. Jamming may be divided into five classifications: Active jamming, Barrage jamming, Off the target jamming, Passive jamming, Spot jamming.

Magnetic field - Field of force to which magnetic materials (e.g., iron) and permanent or electromagnets respond. Surrounds any magnet or electric current. May also be produced in space by a changing electric field. Has both magnitude and direction. May be most easily visualized by iron filings placed in a magnetic field. The filings will align themselves along the field lines.

Modulation - The fluctuation of the amplitude, phase, or frequency of a electromagnetic wave or AC signal. May be deliberately imparted to convey information, or be the result of imperfect implementation or natural causes.

Noise - Unwanted, usually random, electrical or electromagnetic energy that interferes with the detection of wanted signals. The term is also applied to any unwanted random variations in the measured value of any quantity.

Optics - Narrowly, the science of light and vision; broadly, the study of the phenomena associated with the generation, transmission and detection of electromagnetic radiation in the spectral range from the long-wave edge of the x-ray region to the short-wave edge of the radio region. This range often called the optical region or the optical spectrum, extends in wave length from about 1 nanometer to about 1 mm.

Passive guidance - A from of missile guidance in which the missile does not radiate any energy but rather listens to the radiation from the target. In the case of radar guidance, this radiation may be jamming or a signal transmitted by the target as a part of its normal operation.

Phase - Degree of coincidence in time between a repetitive signal, such as a sine wave, and a reference signal having the same frequency. Commonly measured between the points at which the signal and the reference pass through zero in a positive direction. Generally expressed in degrees, 360 degrees corresponding to the period of the signal.

Pixel - Picture resolution element. The smallest resolvable element of an image that may be presented on a given TV-type display.

Polarization - The orientation of the electric and magnetic fields of an electromagnetic wave. In free space, these fields are perpendicular to each other and to the direction of propagation. By convention, the polarization of the wave is the direction of the electric field. If the polarization does not change as the wave propagates, the polarization is said to be *linear*. If the polarization rotates through 360° in every wavelength of travel - as when the horizontal and vertical components of the wave are 90° out of phase - the polarization is said to be *circular* if the amplitudes of the components are the same and *elliptical* if they are not.

Probability of detection (POD) - The probability that a given target will be detected under given conditions at a given range on any one scan of the antenna.

Radar cross section (RCS) - A factor relating to the power of the electromagnetic waves that a radar target scatters back in the direction of the radar to the power density of the radar's transmitted waves at the target's range. Takes account of the cross - sectional area of the target as viewed by the radar, the target's reflectivity, and it's directivity.

Radar signature - Identifying features of or patterns in the returns, a radar receives from targets of a given type.

Radian - Angle of the center of a circle that is subtended by an arc whose length equals the radius of the circle. Approximately 57.3°.

Range - The radial distance from a radar to a target or another object.

Reflection - (1) The process of reradiating an incident electromagnetic wave. Reflection that is mirror-like is called specular. Reflection that is not is called scattering. (2) In an electrical circuit or transmission line, the return of a fraction of an incoming signal to its source when the impedances of two circuits, a transmission line and its load, etc. are not matched.

Reflectivity - The degree to which an object reflects incident electromagnetic waves.

Refraction - The bending of an electromagnetic wave that occurs when the wave passes obliquely from one medium into another whose dielectric constant (or permeability) is different from that of the first medium. The bending results from the speed of the wave's propagation being slightly different in one medium than in the other. Refraction may also occur in a single medium whose dielectric constant (or permeability) gradually changes in a direction normal to the wave's direction of propagation.

Saturation - A condition occurring when the output of a device, circuit, or system has been raised to a point where no further increase is possible in response to an increase of the input.

Scan - To systematically move the pointing direction of the antenna beam so as to cover a prescribed region. Scanning may be done to search for targets, map a given region on the ground, or determine angle tracking errors during single-target tracking.

Scintillation - The rapid fluctuation in the amplitude of the return received from a target (or point on the ground in the case of ground mapping). Is due to change in the relative distances of the various scattering elements making up the target. These changes may be the result of changes in the range, angle, or aspect of the target, even vibration. Slower fluctuations of the return are called fading. Changes in the apparent center of reflection from the target are called glint. The term *scintillation* is also used to describe the turbulence-induced, random variations of local irradiance. This includes the twinkling of starlight, fading in optical communications channels and some speckle effects in radiation distributions at targets.

Signal - (1) The term applied to the desired return from almost any object of interest (target) as opposed to noise or clutter. (2) The term applied to any electrical current or voltage that conveys desired information.

Sniperscope - An IR viewing system for snipping at night without the use of visible light. Sniperscope is usually mounted on the barrel of a rifle. The fundamental component is an image tube which is housed in a long cylinder containing an objective lens on the front end. The image tube is a type of electronic lens, the sensitivity of which is sensitive to IR which is invisible to the human eye. A component housing the light source is attached to the underside of the weapon. An IR filter is applied to the light source to illuminate the target with IR light only. The radiation reflected by the target is imaged by the objective lens onto the photocathode of the image tube. The photocathode emits electrons in direct proportion to the magnitude of the reflected IR radiation. The electrons are accelerated by the image tube and impinge on a persistence screen at the other end of the tube forming a visible image corresponding to the IR image. The visible image is then viewable through the ocular lens.

Spectrum - Distribution of the power or energy of a signal over the range of possible frequencies; is commonly represented by a plot of amplitude versus frequency. If the amplitude is a voltage, a plot of the square of the amplitude is the power spectrum; the area under the power spectrum corresponds to the signal's energy.

Steradian - Unit solid angle. The solid angle at the center of a sphere which is subtended by an area on the surface of the sphere equal to the radius of the sphere squared.

Surveillance - Observing or keeping watch over given region of interest.

Telemetering - The measuring of quantities by telemeter, transmitting and recording the results to a distant station, and, in some instances, integrating the results with others and connecting them electronically into new impulses. The new impulses then activate another cycle of events. A telemeter is an electronic device that measures a quantity and transmits the measurements to a distance station.

Thermal noise - A random voltage appearing across a conductor as a result of the thermal agitation of free electrons in the conductor. The noise power is proportional to the absolute temperature of the conductor.

Threshold - A level established for decision making. In the case of automatic target detection, a target may be deemed to be present if the output of the radar receiver or signal processor exceeds a threshold set high enough to limit the probability of false alarms to an acceptable value.

Tracking - Following a selected target (or targets) in range, angle, or doppler frequency (or some combination of these).

Wavefront - A continuous surface, normal to the direction of propagation of an electromagnetic wave, on which the phases of the wave's electric or magnetic fields are everywhere the same.

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